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ORIGINAL ARTICLES

GROWTH STUDIES ON *SACCHARUM OFFICINARUM*

I. VARIETAL SERIES

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(Received for publication on 15 November 1944)

(With one text-figure)

IN breeding and selection of varieties it is of utmost importance to speed up the process of selection (of an attempted cross at a breeding station) from the stage of a cane seedling to the final stage when it becomes an approved variety fit for distribution to the cane growers. The plant breeders and agronomists are, therefore, now more and more on the look-out for methods that would rapidly facilitate quick selection of varieties. Methods that a few years ago were of fundamental physiological interest have been simplified and modified to suit field environment. Arithmetical procedure to use the physiological data have been reduced to analyseable form. Thus old empirical observational system is rapidly being replaced by newer perfected tests to yield elaborate and accurate information of value regarding the performance of seedlings. Growth in length is one of the important physiological characters of varieties which is interpretable mathematically and which yields information of value for selection of varieties in quick progress. In the paper this aspect has been studied in some detail in the varietal trials.

HISTORICAL

Blackman [1919] enunciated that the rate of growth in plants in general may be expressed according to the compound interest law concept. He further elaborated on the subject and established the importance of r as a measure of the relative growth rate even in such cases where growth had not strictly followed the exponential law. He defined r as the rate or an index of efficiency of the plant as a producer of new material. On the subject considerable criticism was advanced by Kidd, West and Briggs [1920] who had already done work on the problem in some detail. Reviewing these objections Fisher [1921] mathematically showed that the correct measure for the value of relative growth rate over long or short periods was that advocated by Blackman under the concept of efficiency index. He asserted that growth at various stages or time intervals and consequently relative growth rate under the influence of any treatment can best be studied by the logistic or exponential equation. Rather he opined that all biological developments are controlled according to the compound interest law, and hence $H = Ae^{bt}$ can work quite satisfactorily to determine the rate of growth and initial potential or development. This authoritative view left little ground for further controversy on the subject and it simultaneously led the scientists to use the exponential law for determining the rate of growth of crops.

In studying the development in *Musa cavendishii*, Lambert variety of Banana, Summerville [1944] examined data on the efficiency of growth of the leaves and observed that the average efficiency index, i.e. r, was virtually constant for all the plants, which seemingly was conferred by virtue of the genetical constitution. The constancy of r was brought about by the fact that normally the final area increased as t increased. He further confirmed the findings of Gregory [1928] that 'The total growth is not the function of temperature and other external factors,' but is, as stated above, conferred by the genetical constitution of the plant.

Koenigs [1922] from measurements of cane at regular intervals showed that the growth of cane is symptomatic of logistic curve and is considerably influenced by temperature and other environmental factors. Ashby [1930, 1932] employed the results of growth rate for working out the hybrid vigour and the inheritance of efficiency index in maize. Heath [1932] fitted curves of exponential

types from the growth measurement data of some of the South African varieties of cotton and observed that a large value of A in the formula $H = Ae^{bt}$ showed high initial potential of growth of the varieties. This was confirmed by Afzal and Iyer [1934] from statistical analysis of exponential height growth curves of four varieties of cotton—4F, 289F, Early Strain and Mollisoni. Further comparison of values indicated that the Punjab American varieties compared favourably in their rate of growth with the South African varieties studied by Heath. Amongst themselves Punjab American varieties had a lesser growth rate than Mollisoni. Besides, they observed a high coefficient of correlation between the relative growth rate and the mean daily growth rate of the varieties for the whole period of study. Willcox [1930, 1938] suggests that by determining the point of inflection of the curve it is possible to state the period of application of readily available plant food that may be effective in increasing the yield of the crop. From the growth values he also suggests a procedure of determining the manurial requirements of the crop for a particular soil type.

Observational growth data have been successfully utilized by various workers for different purposes. Barber [1918] calculated cane module values of Saretha and Sunnabile groups for two years and showed that the Saretha group values were higher than the values of the Sunnabile group of canes. Again the curves, showing the average length of successive joints from the base to the apex in the Saretha and Sunnabile groups, were two distinct types. The former group of canes developed more rapidly than the latter in all their parts. Barber [1919] also (i) reported on the effect of locality on the growth of indigenous canes, (ii) characters of cane growth in different places, (iii) the effect of season on the length of cane joints and (iv) the periodicity in the length of the joints. From these studies he concluded that '.................... not only had each variety a definite growth character of its own but that each locality and soil had the power of modifying this. So that the growth in each place was the resultant of the inherent characteristic of the type and the external environment to which it is subjected.' The measurements of the various characters were made at harvest and the conclusions drawn were purely from the curves and the averages of the such tabulated data. Using Venkatraman's data he [Barber, 1919] drew some important inferences on tillering phase of the growth of the crop, namely, (*a*) the main shoot was thinner and less developed than its branches, (*b*) the different varieties varied greatly in the maturing of canes, (*c*) the branching in the various groups from the wild *Saccharum spontaneum* to the thick tropical canes was of the same nature but of a different degree and (*d*) average thickness of canes in a group varied inversely with the rate of tillering. Agee [1930] by illustrating the growth made in each of the month of the growth cycle mathematically showed the importance of summer-time and winter-time and thus tried to assess ' the relative growing time value of each month in the year ' for increasing production of sugar. Das [1933] further elaborated the idea and attempted to determine the production of sugar in terms of temperature or as he termed them ' day degrees '. But one of the most important use to which the growth in length data have been put is the determination of the wilting coefficient of soil. Shaw and Sweezy [1937] have reported the comprehensive field investigations carried out on irrigation requirements in Hawaii, which have for their basis the determination of soil moisture at the critical limit of water for plant growth. They described the use of ' long period curves of growth ' in maintaining cane growth without cessation and the indications of the total potential cane lost during the periods when soil moisture fell below the wilting coefficient of the soil. By this procedure, which is now a routine practice at all the plantation estates of the Hawaiian Islands, great economy in the use of water has been effected.

Material and methods

Growth in length. The procedure of selecting shoots, technique of growth measurement, posting of growth measurement data and dissection of stools have already been described by the author [1944] in another connection, wherein a part of the co-ordinated study conducted to evaluate growth characters of varieties and determination of the irrigation requirements of varieties and the influence of different irrigation intervals on the juice quality and yield of cane at harvest have been reported. Ten mother shoots were selected at random, two in each row of the net experimental plot, and growth measurements, taken at regular intervals, were recorded over the entire life cycle of the crop. The results were so tabulated as to obtain cumulative growth in length curves and exponential height

growth curves, for working out the growth constants, i.e. initial rapidity of growth values (A constant), efficiency indices of plant growth, mean daily growth rate, etc.

Underground branching. Barber [1919] has described in detail the procedure of study of underground branching in canes. His procedure was adopted for varietal studies in the two trials conducted in the year 1941-1942. Ten clumps, for each of the varieties, were examined at harvest.

These clumps had been under close study from the early time of their germination when they had been tagged. As shoots appeared they were serially numbered and deaths if any occurring were recorded at regular intervals. So that at the time of dissection the clump could be separately analysed for (*a*) cane forming shoots, which we have termed as mature shoots, (*b*) shoots not cane forming, named as immature shoots, (*c*) healthy shoots, that is those stalks which were unaffected by borers, white ants, etc. at any stage of their life and (*d*) diseased shoots which had been affected at some stage or the other by insects, diseases and other physiological causes. Of these healthy and diseased shoots both immature and mature shoots come under these sub-heads so that interactions could be worked out amongst varieties and any other of the above subgroups.

The studies were very laborious and required dissection of the stools by the author himself; these, therefore, could not be repeated during the following season, when analysis of the data were carried out.

Millable cane characters. Each of the mature canes, from the various clumps, dissected for analysis, was weighed, its total length recorded and its girth at three mid-joints, i.e. top, middle and bottom joints was noted. Instead of the radial and medial thickness of joints as had been recorded by Barber [1915] girth measurements gave better values for the mean thickness of the joints. Ratios between mean total length of the canes and their mean thickness of joints were worked out and have been noted as cane module values. For instance in one case the cane module value was worked out as follows :—

Mean cane length$=188{\cdot}5\pm51{\cdot}18$ cm.
Mean cane girth$=6{\cdot}9\pm0{\cdot}87$ cm.
Therefore, mean thickness$=6{\cdot}9\times7/22=2{\cdot}196$ cm.
Hence, cane module$=188{\cdot}5/2{\cdot}196=85{\cdot}9$ or 86.

The figure 86 represents, in round numbers, the cane module value of the variety of which the results are given above and is in the nature of an index used by Barber [1918] to indicate group differences in the Indian canes of Sunnabile and Saretha groups. We have, however, recorded all these data with a view to differentiate millable cane characters amongst the varieties.

Procedure of analysis of the experimental data

Fitting of growth curves and testing significance. Blackman and others working with dry weights of plants have used the compound interest concept, whereas we have to deal with growth in length data so that according to Heath [1932] the formula to be used becomes

$$H= \quad Ae^{bt}$$

where, A is the length attained by an initial time, H is the final length attained, b is the rate or an index of 'efficiency of the plant as a producer of new material', t is the time and e is the base of natural logarithm. With seed plants the original point indicated is the embryo weight. But with sugar cane where setts are planted no such well defined point is apparent. Therefore, the initial point in most cases was taken soon after the germination of the crop was completed. In a few cases the initial point was taken much later in view of unavoidable circumstances which necessitated postponing the studies for a time. For comparative results in the same year, as had been shown by Summerville [1944], it did not matter.

Correlation of growth A and b values. Correlation coefficient was determined between the inherent growth factor A and the ultimate yield of the varieties on the one hand and between the relative growth rates (b values) of the varieties and their mean sugar contents during the crushing season on the other and for doing so there is some justification, for the deductions obtained from the correlations have a sound physiological interpretation of the data. This has, however, been discussed in a later part of the text.

Mean daily growth rate. The average daily growth rates of the varieties were worked out by the formula log $e\ H_2$—log $e\ H_1/n'$, where H_2 is the final height, H_1 is the initial height and n' is the number of days from H_1 to H_2 [Afzal and Iyer, 1934]. The average daily growth rates of different varieties in the various trials were worked out for comparison against the efficiency index values (relative growth rates) of the varieties. The values of the coefficient of correlation between mean daily growth rates and the relative efficiency indices were also worked out.

Evaluation of the parameters and their relationship to the varietal performance

Physiological experiment—1940-1941 series. The work was begun in the year 1940 on a trial consisting of varieties Co290, Co281, Co331, Co205 and Co432. It was in the nature of a physiological experiment with widely divergent varietal material. These varieties were planted in four randomized blocks on a loam soil. During germination and up to the middle of April, the field was irrigated at ten days intervals. Later on irrigations were applied when the soil attained critical moisture limit for active cane growth of the crop. The interval was determined by the approach of the wilting coefficient of the soil within the first six inches of the soil which was noticed to cause a setback in the active cane growth of the crop.

Cumulative growth in length. The results of the cumulative growth in length of the varieties have been shown in Fig. 1. All the varieties had normal form of the sigmoid curves and had almost equal stand till about the 95th day after planting when differences in growth amongst the varieties began to manifest themselves more apparently. The point of inflection in the boom stage was noticed on 130th day. The grand growth period extended up to 180th day. The active growth was maintained for another month. From 210th day the curve of growth tended to run parallel to ordinate. Individually Co331 maintained somewhat higher rate of growth up to 195th day when the curve of absolute growth of Co290 outstripped it. Varieties Co205 and Co432 behaved identically. The former generally had a slightly higher rate of growth than the latter. The growth curve of Co281 was distinctly different from rest of the varieties. It occupied a mid-position up to 125th day when a lag in it began to appear. At harvest it had the lowest stand.

Exponential height growth curves. The calculated exponential height growth curves of the varieties are given in Table I below.

TABLE I

Exponential height growth curves

Variety	Number of observations	Equation $H=Ae^{bt}$	S.E. of b	Mean yield per acre in md.	Mean sucrose content juice (percentage)
Co205	55	$H=2{\cdot}179e^{0{\cdot}01677t}$	0·000780	637	11·22
Co281	55	$H=3{\cdot}589e^{0{\cdot}01782t}$	0·000947	384	13·30
Co290	55	$H=4{\cdot}137e^{0{\cdot}01799t}$	0·001029	524	11·40
Co432	55	$H=4{\cdot}481e^{0{\cdot}01594t}$	0·001218	706	8·44
Co331	55	$H=4{\cdot}575e^{0{\cdot}01652t}$	0·001015	784	10·76

The two parameters estimated are fairly clearly shown in the exponential height growth curves. The statistical comparison of b values showed that the efficiency index values of variety Co281, in order, was significantly greater than Co432, Co331 and Co205 at five per cent level of significance and that of Co290 at 10 per cent level of significance. Viswa Nath [1919] had shown that side by side with the elongation of the cane stem there occurs an accumulation of sugar in the cane joints. Physiologically, therefore, the relative growth rate should correspond to the sucrose content in the cane. The value of the coefficient of correlation between the efficiency indices of the varieties and their mean sucrose performance during the crushing season was, therefore, worked out. The value

$+0{\cdot}97$ ($>P=0{\cdot}01$) was observed to be highly significant. The importance of these results in the selection of varieties pertaining to the environment has been emphasised later in the text.

Early growth of the varieties does not appear to very much influence the yield of the varieties as the correlation between the parameter A and the yield values was observed as non-significant. The low value worked out was $+0{\cdot}28$ only.

The growth studies in the following year were extended to the medium-early and mid-season varietal trials.

Medium-early series

The varieties planted in the medium-early series, now under review, were Co312 (Standard), Co281, Co313, Co299, Co427 and Co549. These varieties were selected on the basis of yield and sugar performance from the multiplication series at the close of 1940-1941. Variety Co312, which served as standard in the trial, in reality is a mid-season cane. This was included to see how far the medium-early canes were comparatively lower in acre yields and if the extra yield of sugar on cane, early in the season (mid-December), in the highest yielding medium-early variety could compensate for the loss in yield as compared to the standard in the trial. For the first two seasons the growth measurements were recorded on the plant crop of the varieties in the trial. In the final year the preceding year's trial was ratooned and growth measurements on the ratooned varieties were recorded.

Cumulative growth curves. A detailed study of cumulative growth curves of the varieties indicated some differences worth recording. In the first season of study, the formative period of the crop growth extended over 70 days. The mean growth made by varieties was about 19 cm. The boom stage lasted for 130 days and in this period the mean growth accumulated was 216 cm. In the senescent phase the accumulation was 50 cm. of the total growth made by then and this phase extended over a period of 45 days. In the next year the formative period covered 130 days in which period on the average all varieties accumulated about 18 cm. of growth. Correspondingly the boom stage was reduced to 90 days and in this period plants made up a stand of 139 cm. The senescent phase was short and consisted of 25 days only, in which period it accumulated 12 cm. of growth. The medium-early ratoon crop had a moderately long formative period of 110 days. During this period the plants accumulated 125 cm. Boom period lasted for 100 days and in this period the plants accumulated 125 cm. of growth. In the senescent phase of 70 days the plants accumulated 13 cm. of growth only. Thus a considerable variation in the lengths of formative, boom and senescent phases of growth of the crop is observed in different years. Besides it is noticed that an extended formative period is not of any special advantage. Increase in the length of the senescent phase also does not confer any benefit on the plants. From the results it is conceiveable that an extended boom period relatively proves to be of some advantage to the crop.

Individually varieties in the same year also showed differences of interest. Generally, Co427 maintained the highest level of cumulative growth throughout the life cycle of the crop. In the early formative stages Co312 slightly had a better stand than Co427. It is probably this very early start, coupled with greater tillering, that accounts for higher yield of Co312 as compared to Co427 in spite of the better growth of the latter in the grand growth period of the crop. Then we have another set of varieties, namely, Co549, Co299, Co281 and Co313, which had lesser accumulation in the formative period and a comparatively earlier decline of the curve in the senescent phase of the crop. All these varieties generally exhibited high sugar content. Highest early maturity was shown by variety Co281 which had the maximum lag in the tail end of the curve of cumulative growth in length. All the curves of cumulative growth in length were of normal sigmoid type.

In 1942-1943 the curve of cumulative growth in length of variety Co312 in the initial stages had distinctly a better stand than others. At the point of inflection when varieties entered the grand growth period, in comparison to Co313 and Co299, the curve of Co312 began to indicate a lag. The differences widened as the crop entered upon its maturition stage. This lag was more pronounced in the curve of Co427 than that of Co312. Varieties Co299 and Co549 indicated an identical behaviour through the formative, grand growth and senescent phases of the crop. Co313 had a lower start in the formative period ; in the boom period its curve of cumulative growth in length crossed over others and stood the highest at the close of the maturity period.

The curve of cumulative growth in length of variety Co427 in the crop season 1943-1944 (ratooned crop) through the formative, grand growth and senescent phases had the highest stand. Thus it could maintain a higher growth level than Co281 and Co312 till the sigmoid curves sloped down to run parallel to the ordinate, i.e. when the crop had entered upon its senescent phase. Varieties Co299 and Co549 started with a low absolute increase in height and growth and accumulated less and less of height as time elapsed.

Collectively the varieties generally showed less growth during the months of April, May and June in 1942-1943 as compared to the year 1941-1942. In both these years varieties compared were of plant crop. During July to September the growth in the two years was almost comparable but was again smaller in the latter year in the months of October and November than in the crop season of 1941-1942. Amongst the varieties, Co427 generally in all the months exhibited the depressing effect of the environment more than other varieties. Variety Co281 indicated relatively greater lag in the months of October and November than in other months, although in the perceding two months, i.e. in August and September, contrary to the general trend of the varieties, the growth accumulated was more in 1942-1943 than in the year 1941-1942. Variety Co313 exhibited such a feature in the months of July and August.

Exponential height growth curves. The results of the calculated exponential height growth curves of the varieties in the medium-early series for the three seasons are given in Table II.

TABLE II

Exponential height growth curves

Variety	Equation $H=Ae^{bt}$		
	1941-1942 (Plant crop)	1942-1943 (Plant crop)	1943-1944 (Ratoon crop)
Co312 (St.) . . .	$H=12{\cdot}34e^{0{\cdot}01435t}$	$H=5{\cdot}68e^{0{\cdot}01284t}$	$H=12{\cdot}55e^{0{\cdot}01034t}$
Co427 . . .	$H=11{\cdot}10e^{0{\cdot}01556t}$	$H=2{\cdot}50e^{0{\cdot}01653t}$	$H=17{\cdot}53e^{0{\cdot}01076t}$
Co549 . . .	$H=9{\cdot}42e^{0{\cdot}01544t}$	$H=2{\cdot}03e^{0{\cdot}01829t}$	$H=9{\cdot}74e^{0{\cdot}01104t}$
Co299 . . .	$H=8{\cdot}63e^{0{\cdot}01595t}$	$H=1{\cdot}82e^{0{\cdot}01842t}$	$H=9{\cdot}60e^{0{\cdot}01049t}$
Co313 . . .	$H=7{\cdot}53e^{0{\cdot}01643t}$	$H=2{\cdot}35e^{0{\cdot}01786t}$	$H=8{\cdot}69e^{0{\cdot}01247t}$
Co281 . . .	$H=6{\cdot}44e^{0{\cdot}01785t}$	$H=1{\cdot}97e^{0{\cdot}01848t}$	$H=6{\cdot}68e^{0{\cdot}01345t}$

In the crop season 1941-1942 varieties Co312 and Co427 had comparatively very rapid growth in the initial stages, which period corresponded to the formative stage of the varieties. Varieties Co549 and Co299 had a medium rapid initial growth and varieties Co313 and Co281 took the slowest initial start.

In relative growth rate, i.e. with regard to b values the order of varieties was almost reversed. Variety Co312 had the least relative growth rate ; Co427, in spite of its high initial start, correspondingly had a fairly high relative growth rate of elongation, which is comparable to those of varieties Co549 and Co299, but it is definitely less than those of varieties Co313 and Co281. Statistically the relative growth rate of Co281 was significantly greater than that of Co427, Co549 and Co312, the differences amongst Co281, Co299 and Co313 being not significant. Again, statistically the values of Co313, Co299 and Co427 were the same at 5 per cent level of significance. But all the varieties, namely, Co281, Co313, Co299 and Co427, had significantly higher growth rate values than Co312, the difference between the values of varieties Co312 and Co549 being not significant.

It is evident from a comparison of the equations for the different varieties in the two seasons, i.e. 1941-1942 and 1942-1943, that A values generally were lower and b values higher in the latter than in the former season. In fact A values of varieties Co299, Co427 and Co549 were much more depressed than those of the varieties Co313 and Co281. When the A values of the variety Co312 is taken as normal for the two seasons, a comparison of the values of other varieties is possible. This

is shown in Table III. The former three showed over 40 per cent depression compared to about 18 per cent in the latter two.

TABLE III

Relative values of parameter

Varieties	1941-1942		1942-1943		Percentage differences in two years in *A* values
	Parameter *A* values	Percentage of maximum	Parameter *A* values	Percentage of maximum	
Co312	12·34	100·0	5·68	100·0	..
Co427	11·10	90·0	2·50	44·0	46·0
Co549	9·42	76·3	2·03	35·7	40·6
Co299	8·63	80·0	1·82	32·5	48·5
Co313	7·53	61·0	2·35	41·3	19·7
Co281	6·44	52·2	1·97	34·6	17·6

In a similar manner the differences amongst the *b* values of the varieties in the two seasons are shown in Table IV ; percentage differences in the two seasons are shown in last column of the table. The differences were more appreciable in varieties Co299, Co549 and Co312 than in others. These

TABLE IV

Relative values of parameter b

Varieties	1941-1942		1942-1943		Percentage differences in two seasons
	Parameter *b* values	Percentage of maximum	Parameter *b* values	Percentage of maximum	
Co281	0·01785	100·0	0·01848	100·0	..
Co313	0·01643	92·0	0·01786	96·6	—4·6
Co299	0·01595	89·3	0·01842	99·6	—10·3
Co427	0·01556	87·2	0·01653	89·4	—2·2
Co549	0·01544	86·5	0·01829	98·9	—12·4
Co312	0·01435	80·4	0·01284	69·4	+11·0

differences in both the parameters may be attributed to the edaphic and weather differences, the effect of which has been discussed later.

The data for the worked-out exponential height growth curves for the ratoon crop of 1943-1944 season have also been summarized in Table V. It will be noticed that variety Co427 had the highest *A* value ; the next high value was that of variety Co312, varieties Co549, Co299 and Co313 had almost equal values, while Co281 had the lowest value of all the varieties in the trial. In respect of relative growth rate or *b* values Co281 had the highest value, the next higher value was that of Co313. The values in other five varieties were not appreciably different one from the other.

TABLE V

Correlation coefficients

Parameter A = A ; mean yield per acre in md. = B ; parameter b = C ; mean sucrose percentage in juice = D

Variety	Growth constants, yield and sucrose data											
	1941-1942				1942-1943				1943-1944			
	A	B	C	D	A	B	C	D	A	B	C	D
Co312	12·34	767	0·01435	10·23	5·68	552	0·01284	10·99	12·55	806	0·01034	12·05
Co427	11·10	637	0·01556	11·35	2·50	430	0·01653	12·35	17·53	741	0·01076	13·02
Co549	9·42	453	0·01544	12·06	2·03	400	0·01829	12·61	9·74	641	0·01104	14·37
Co299	8·63	499	0·01595	12·32	1·82	432	0·01842	12·66	9·60	596	0·01049	13·29
Co313	7·53	656	0·01643	11·96	2·35	449	0·01786	13·11	8·69	716	0·01247	13·34
Co281	6·44	375	0·01785	13·31	1·07	321	0·01848	13·56	6·68	574	0·01345	14·53
Coefficient of correlation	+0·326		+0·926		+0·818		+0·915		+0·556		+0·711	
Significant at	..		P=0·01		P=0·05		P=0·01		..		P=0·10	

Correlations were worked out between A values of varieties and their mean values for the yields of all the replications of the trial on the one hand and between the relative growth rate values of the varieties and their mean sucrose percentage in juice over the entire crushing season. The summarized data have been presented in Table V. The value of the correlation coefficient between the mean yield of the varieties and their initial rapidity of growth values was low in the year 1941-1942 ; it was significant at 5 per cent level in the year 1942-1943 and moderate in the crop season 1943-1944, but not significant even at 10 per cent level of significance. Correlation coefficients between the relative growth rates of the varieties and their mean sucrose percentage in juice were significant in all the three years. In the first two seasons the values were very high while in the third season, i.e. in 1943-1944 it was significant at 10 per cent level only. The results thus indicate that the yield is influenced by the initial rapidity of growth and the accumulation of sugar is closely bound up with the relative rates of growth of the varieties. The significance of these results has been discussed later.

MID-SEASON SERIES

In the mid-season series the varieties included were Co290 (St.), Co312, Co331, Co419, Co438, Co451 and Co534. Growth in length record were obtained for three seasons, namely, 1941-1942, 1942-1943 and 1943-1944. In the crop season 1942-1943 the preceding year's trial was ratooned and experimental record was obtained on the ratoon crop also to compare the performance of the varieties with the plant crop of the same season.

Cumulative growth in length. Cumulative growth curves of varieties, drawn to figure the differences in the various periods of growth in the life cycle of the plants, in the crop season 1941-1942, indicated that varieties Co290, Co312 and Co438 behaved fairly identically and ran a parallel course through the three phases of growth ; variety Co534 maintained distinctly a low level of growth in the formative, grand growth and senescent phases of the crop life ; and the rest of the three varieties, namely, Co331, Co419 and Co451 showed different performance in the various phases. Variety Co331 with a very high growth level in the formative period indicated a lag in the latter two phases.

Variety Co451 kept up a high growth level only up to the earlier part of the boom period, later on a lag was evident but it was less pronounced than in Co331. Variety Co419 had a low growth level in the formative and up to mid-boom stage, after mid-boom stage there was a rise in the cumulative growth curve of the variety.

Under the environmental conditions prevailing in the crop season 1942-1943 variety Co331 in the plant crop series had accumulated the largest amount of growth. It took a start in the formative period and maintained it up. Variety Co290 though had some lag in the early growth stage stole a march over other varieties beyond the point of inflection. Varieties Co419, Co438 and Co534 had a tardy start in the initial stages. During the mid-boom stage its growth level was enhanced and it had greater cumulative growth in length than the remaining two varieties, namely, Co312 and Co451, by the close of the senescent phase, which, in spite of the good start in the formative period, showed a lag in the boom and senescent phases of growth of the plants. Such a lag in variety Co312 was apparent in the medium-early series of this year also.

In the ratoon crop the cumulative growth in length of varieties Co451 and Co534 was superior than that of the plant crop. Variety Co331 had as good accumulation of growth in the ratoon as in the plant crop of that season. Co534 when ratooned ran a course very close to Co331 over all the phases of crop growth, while the curve of growth of variety Co451 slightly deviated away from Co331 when the sigmoid curve during the senescent phase tended to run parallel to the ordinate. Similarly the cumulative curves of growth of varieties Co419 and Co438 ran a parallel course through the three phases of growth, but their rate of increment of growth accumulation was smaller than that of Co331, Co534 and Co451. Varieties Co290 and Co312 maintained a lead over Co419 and Co438 till the mid-boom stage when Co312 showed a rapid falling off in growth while Co290 kept on close to the growth curves of varieties Co419 and Co438. The cumulative effect of growth was more apparent towards the maturation or senescent phase of the crop.

In the year 1943-1944 curves of cumulative growth in length of varieties Co331, Co451, Co290 and Co312 with slight variations ran a parallel course through all the phases of cane growth. In the preceding year the environment was not so suitable for rapid accumulation of growth in the case of Co290 and Co312 as in the year under report. The remaining varieties that could be grouped together were Co438, Co419 and Co534. The curves of growth of these varieties tended to deflect away from the course of the former group from the mid-boom stage onwards as the curves tended to run parallel to the ordinate.

Scanning over the mean values of all the varieties in the different years one finds that the formative period in the year 1941-1942 lasted for 45 days only and in this period the mean accumulation of growth was 13 cm. The boom period extended over 150 days in which plants accumulated 217 cm. In the senescent phase 22 cm. of growth was added within 50 days. Compared to this in the following year plant crop had formative period extended by another 35 days in which extra growth accumulated was only 5 cm. Proportionately, thus, the boom period was reduced by a corresponding period and lasted for 100 days only. In this span of life the growth accumulated was 146 cm. In view of the short grand growth period senescent phase was prolonged by another 15 days, but the environment being not very favourable the growth accumulated was 13 cm. only compared to 22 cm. in the preceding year. The ratoon crop had an extended period of crop growth by about 40 days and this helped in greater accumulation of growth, the comparative accumulated lengths in plant and ratoon crops being 146 and 221 cm. respectively. The 1943-1944 series had fairly long formative period with small growth accumulation. The boom period lasted over a short period of 110 days when plants accumulated 148 cm. It is in the senescent phase that the plants accumulated rather more than in the preceding year. Within a period of 50 days the accumulation was 70 cm. as against 65 days and 13 cm. in the crop season 1942-1943. These interesting differences in crop growth have their significance in explaining some of the peculiarities in varieties. These have been pointed out later on.

Exponential height growth curves. In Table VI are given the results of worked out exponential height growth curves for the three seasons in which studies were carried out. The data for the ratoon crop of the year 1942-1943 is also included in Table VI for comparison with the plant crop of the same year.

TABLE VI

Exponential height growth curves

Varieties	Equation—$H=Ae^{bt}$			
	1941-1942 (Plant crop)	1942-1943 (Plant crop)	1942-1943 (Ratoon crop)	1943-1944 (Plant crop)
Co331	$H=11\cdot52e^{0\cdot01472t}$	$H=7\cdot56e^{0\cdot01744t}$	$H=5\cdot00e^{0\cdot01532t}$	$H=10\cdot13e^{0\cdot0134t}$
Co312	$H=9\cdot98e^{0\cdot01598t}$	$H=5\cdot83e^{0\cdot01677t}$	$H=4\cdot19e^{0\cdot01474t}$	$H=11\cdot06e^{0\cdot01323t}$
Co290 (St.)	$H=9\cdot36e^{0\cdot01687t}$	$H=6\cdot91e^{0\cdot01686t}$	$H=5\cdot96e^{0\cdot01396t}$	$H=8\cdot03e^{0\cdot01499t}$
Co438	$H=8\cdot34e^{0\cdot01739t}$	$H=5\cdot46e^{0\cdot01742t}$	$H=3\cdot04e^{0\cdot01639t}$	$H=7\cdot75e^{0\cdot01454t}$
Co451	$H=7\cdot62e^{0\cdot01759t}$	$H=4\cdot53e^{0\cdot01537t}$	$H=0\cdot68e^{0\cdot02393t}$	$H=8\cdot96e^{0\cdot01455t}$
Co419	$H=6\cdot39e^{0\cdot01809t}$	$H=4\cdot53e^{0\cdot01885t}$	$H=3\cdot18e^{0\cdot01639t}$	$H=8\cdot46e^{0.01399t}$
Co534	$H=4\cdot34e^{0\cdot01824t}$	$H=3\cdot76e^{0\cdot01848t}$	$H=1\cdot25e^{0\cdot02181t}$	$H=2\cdot12e^{0\cdot02182t}$

A perusal of the plant crop data for the season 1941-1942 revealed wide variations in the two parameters determined from the curves. Parameter A was the highest in Co331, indicating the highest growth rate in the initial stages of the crop. Value A of the variety Co534 was the least. Evidently it possessed the lowest initial potential of growth of all the varieties in the trial. The other varieties had A values in between the A values of these two varieties. Statistically Co331 had significantly higher A value than that of varieties Co438, Co451, Co419 and Co534, those of Co312 and Co290, equal between themselves, were greater than Co419 and Co534, and those of Co438 and Co451 greater than Co534 only.

The parameter A values of the various varieties, in the crop season 1942-1943, were of a different order than in 1941-1942. For instance Co290 and Co451 had higher value than Co312. Statistically critical difference at $P = 0\cdot05$ worked out to 1·198 cm. Thus A value of Co331 was greater than that of Co312, Co438, Co419 and Co534, of Co290 was greater than that of Co438, Co419 and Co534, of Co451 and Co312 were greater than that of Co419 and Co534; Co438 alone had a significantly higher A value than that of Co534.

In the final year the crop plant of the mid-season series indicated a slightly different order of its A values from those in each of the two preceding years. The A value of Co534 was exceptionally low as compared to A values of the other varieties. The critical difference for the series was 1·087 cm. at $P = 0\cdot05$. Between themselves Co312 and Co331 statistically showed non-significant difference while they had significantly greater A values than rest of the varieties. Varieties Co451, Co419, Co290 and Co438 had significantly higher A values than Co534.

A comparison of A values of the varieties, in the mid-season plant crop trial, in the three seasons, indicates that the parameter A values, without consideration of the individual variations, for the crop season 1942-1943 were generally lower than that of either 1941-1942 or 1943-1944. It is also noticed that the ratoon crop values of the initial growth in length in this year were further lower than the plant crop. This was so collectively for the trial as well as individually for every one of the varieties. Obviously environmental differences must have brought about these differences. On this point we have gone in some detail in the succeeding portion of the text.

Parameter b values in the crop season 1941-1942 showed significant differences amongst the varieties. Variety Co331 had a significantly lower value than that of Co534, Co419, Co451, Co438 and Co290, but statistically it was equal to that of Co312, which in turn also showed non-significant differences over that of the former five varieties.

In the crop season 1942-1943 the parameter b was the lowest in the case of Co451 and not Co331 which had higher value than that of the varieties Co312 and Co290. Statistically parameter b value of Co534 was significantly higher than that of Co451 and Co312 and that of Co419 higher than the value of Co451 alone. The differences amongst others were not significant.

The parameter b values of variety Co534, again, was the highest in the third year of study and showed a significant difference over all others. The lowest value was recorded for the variety Co312. The varieties Co290, Co438, Co451, Co419, Co331 and Co312 did not show significant differences amongst themselves.

A comparison of the b values of the plant crop as against the ratoon crop showed differences in some important respects. As plant crop Co451 had the lowest value, but as ratoon crop it had a fairly high b value. On the other hand Co419 as plant crop had a fairly high value but as ratoon crop its value was considerably reduced. Similar position was noticed in the case of Co290 and Co312.

Though the comparison of the parameter A and b values is important to assess the performance differences of the varieties in the various years, it is still more important to know how these figures are correlated to the yields or mean sugar values in the different seasons. A comparison is provided in Tables VII and VIII.

TABLE VII

Values of parameters A *and acre yields*

Parameter A value=A ; Mean yield per acre in md.=B

Varieties	1941-1942 Plant crop		1942-1943 Plant crop		1942-1943 Ratoon crop		1943-1944 Plant crop	
	A	B	A	B	A	B	A	B
Co331	11·52	1071	7·56	339	5·00	1012	10·13	368
Co312	9·98	944	5·83	457	4·19	744	11·06	515
Co290 (St.)	9·36	743	6·91	375	5·96	664	8·03	368
Co438	8·34	838	5·46	429	3·04	529	7·75	408
Co451	7·62	916	6·55	272	0·68	644	8·96	317
Co419	6·30	911	4·53	182	3·18	709	8·46	389
Co534	4·34	756	3·76	272	1·25	534	2·12	267
Coefficient of correlation	+0·41		+0·382		+0·534		+0·817 ($>P=0·05$)	

The values of the correlation coefficients worked out between parameter A values and the mean yield values in all cases gave positive correlations. The value was significant for the crop season 1943-1944 only. In the case of medium-early varieties trial, a similar position was noticed which indicates that the initial rapidity of growth, although influencing the yield, is not the major factor determining the yields of the varieties.

The parameter b and mean sucrose values of the varieties in the different crop seasons are shown in Table VIII.

TABLE VIII

Values of parameter b and mean sucrose percentage in juice

Parameter b values=A ; Mean sucrose per cent in juice=B

Varieties	1941-1942 Plant crop		1942-1943 Plant crop		1942-1943 Ratoon crop		1943-1944 Plant crop	
	A	B	A	B	A	B	A	B
Co331	0·01472	8·84	0·01744	12·58	0·01532	12·18	0·01343	14·46
Co312	0·01598	9·23	0·01677	11·47	0·01474	12·37	0·01323	13·50
Co290 (St.)	0·01687	9·71	0·01686	12·12	0·01396	11·50	0·01499	13·77
Co438	0·01739	8·71	0·01742	11·73	0·01639	11·91	0·01454	14·83
Co451	0·01759	9·28	0·01537	12·04	0·01393	13·55	0·01455	14·46
Co419	0·01809	9·24	0·01885	12·62	0·01639	12·22	0·01399	13·77
Co534	0·01824	11·16	0·01948	13·11	0·02181	13·18	0·02182	15·71
Coefficient of correlation	+0·593		+0·713 ($>P=0·10$)		+0·933 ($>P=0·01$)		+0·785 ($>P=0·10$)	

The values of the coefficients of correlation worked out between the relative growth rates of the varieties and their mean sucrose content values are shown in the last horizontal column of Table VIII. In 1941-1942 the value was not high enough to show significance even at $P = 0{\cdot}10$. For the ratoon crop in the year 1942-1943 the value was very highly significant. In the cases of plant crop in the two years, namely, 1942-1943 and 1943-1944, the correlation coefficients indicated were strong and the values were significant at $P = 0{\cdot}10$. Thus we observe that relative growth rate values have much to do with the accumulation of sugar in the juice. A high rate indicates greater accumulation and *vice versa*. Later on these results in conjunction with those of the medium-early series have been discussed.

RELATIONSHIP BETWEEN EFFICIENCY INDICES AND MEAN DAILY GROWTH RATES OF VARIETIES

From the above it is evident that efficiency indices are highly correlated to the mean sucrose percentage in the juice of the varieties. The values, as we know from the mathematical evaluation, also takes into account the mean daily growth rates of the varieties. Let us then find out if it is so in the case of sugar cane as has been shown by Afzal and Iyer [1934] in cotton. The data given in Table IX summarizes the results of comparison.

TABLE IX

Comparison of mean daily growth rate and relative growth rate

Crop season and nature of trial	Varieties	Initial measurement in cm. = H_1	Final measurement in cm. = H_2	Number of days H_1 to H_2	Mean growth rate	Efficiency indices	Value of r
1940-1941— Physiological series (Plant crop)	Co331 .	5·91	197·80	216	0·01623	0·01652	
	Co432 .	7·33	188·28	216	0·01501	0·01594	
	Co290 .	6·45	198·86	216	0·01587	0·01699	−0·016
	Co281 .	7·28	179·46	216	0·01484	0·01762	
	Co205 .	7·31	188·84	216	0·01493	0·01677	
1941-1942— Medium-early series (Plant crop)	Co312 .	18·11	227·38	192	0·01318	0·01436	
	Co427 .	16·90	236·08	192	0·01372	0·01556	
	Co549 .	17·21	215·76	192	0·01317	0·01544	+0·0301
	Co299 .	16·50	215·45	192	0·01338	0·01595	
	Co313 .	13·89	208·69	192	0·01419	0·01663	
	Co281 .	16·02	208·68	192	0·01337	0·01735	
1941-1942— Mid-season series (Plant crop)	Co331 .	11·28	244·06	217	0·01377	0·01472	
	Co312 .	8·24	265·64	217	0·01600	0·01598	
	Co290 .	10·39	235·26	217	0·01638	0·01687	
	Co438 .	8·77	261·43	217	0·01564	0·01739	+0·794
	Co451 .	6·46	237·32	217	0·01661	0·01759	
	Co419 .	6·83	232·66	217	0·01640	0·01811	
	Co534 .	4·90	224·32	217	0·01762	0·01824	
1942-1943— Medium-early series (Plant crop)	Co312 .	12·68	178·06	207	0·01129	0·01284	
	Co427 .	8·89	148·98	207	0·01362	0·01653	
	Co549 .	7·77	190·06	207	0·01559	0·01829	
	Co299 .	8·45	182·23	207	0·01484	0·01842	+0·981
	Co313 .	9·17	198·51	207	0·01485	0·01786	
	Co281 .	8·54	190·17	207	0·01499	0·01848	
1942-1943— Mid-season series (Plant crop)	Co331 .	14·02	228·48	198	0·01410	0·01744	
	Co312 .	11·52	155·71	198	0·01315	0·01677	
	Co290 .	11·22	189·43	198	0·01427	0·01686	
	Co438 .	11·15	170·47	198	0·01377	0·01742	+0·925
	Co451 .	13·15	155·77	198	0·01248	0·01537	
	Co419 .	7·05	178·54	198	0·01632	0·01885	
	Co534 .	7·57	167·89	198	0·01565	0·01948	

TABLE IX—*contd.*

Comparison of mean daily growth rate and relative growth rate—contd.

Crop season and nature of trial	Varieties	Initial measurement in cm. = H_1	Final measurement in cm. = H_2	Number of days H_1 to H_2	Mean growth rate	Efficiency indices	Value of r
1942-1943— Mid-season series (Ratoon crop)	Co331	15·45	283·00	199	0·01472	0·01532	
	Co312	12·12	211·39	199	0·01440	0·01474	
	Co290	16·78	236·07	199	0·01329	0·01396	
	Co438	15·10	239·67	199	0·01412	0·01639	+0·651
	Co451	10·11	264·69	199	0·01641	0·02393	
	Co419	12·13	243·55	199	0·01507	0·01639	
	Co534	17·42	289·75	199	0·01413	0·02181	
1943-1944— Medium-early series (Ratoon crop)	Co312	21·50	149·88	166	0·01170	0·01034	
	Co427	30·35	231·49	166	0·01224	0·01076	
	Co549	18·50	138·20	166	0·01225	0·01104	
	Co299	17·15	117·19	166	0·01158	0·01049	+0·850
	Co313	19·85	173·74	166	0·01307	0·01247	
	Co281	19·25	159·34	166	0·01273	0·01345	
1943-1944— Mid-season series (Plant crop)	Co331	14·40	178·76	162	0·01556	0·01343	
	Co312	14·20	175·94	162	0·01554	0·01323	
	Co290	16·55	176·58	162	0·01464	0·01499	
	Co438	11·75	158·86	162	0·01608	0·01454	+0·0209
	Co451	11·80	182·46	162	0·01690	0·01455	
	Co419	11·15	153·67	162	0·01619	0·01399	
	Co534	11·00	152·64	162	0·01623	0·02182	

Correlation coefficients between the two entities in each of the trials were separately worked out. In three cases out of eight the values were extremely low indicating that there did not exist any relationship between the relative growth rate and the mean daily growth rate of the crop in these trials. In one case, i.e. the ratoon crop of the mid-season series of 1942-1943, the correlation was found to be not significant, though the value indicated a relationship. In rest of the four cases the coefficients of correlation were significant. A correlation between the two was worked out for all the observations irrespective of the years, varieties or nature of the crop. A high correlation value was obtained ($r=0{\cdot}5766>P=0{\cdot}01$). This showed that mean daily growth rate for the four years' period on the whole was a good general index. Although this gross correlation between the two entities might lead one to assume that for all practical purposes the mean daily growth rate is a good measure of relative rate of growth of the crop, for it will reduce the labour of handling the data the individual correlation values point to the fact that the true measure of relative growth in plants is the one worked out by the concept of compound interest law as expounded by Blackman and daily growth rate, at best, is only a most probable indication of the performance of the variety in relation to others in the trial.

FORMATIVE GROWTH VALUES OF THE VARIETIES

In the growth of the plant it is not enough to study the growth in length alone, other factors must also be taken into account as distinct growth features of the varieties. Formative growth values of the varieties are some such factors of importance. These differences chiefly relate to the morphological characters specific to the different varieties in respect of the canes in the clump. Such characters have been studied in two trials, namely, mid-season and medium-early series.

Medium-early varieties. In Table X are given the underground branching data of the varieties in the medium-early trial. It will be noted that the data are complete for five varieties only. For unavoidable reasons all the stools of variety Co281 could not be dissected. Only five clumps of

this variety could be analysed. Therefore, the results for the five varieties are amenable to statistical analysis which is detailed in Table XI. It will be observed from Table X that varieties Co299, Co549, Co313 and Co281 in general showed more tillering than varieties Co312 and Co427. The former four varieties behave as early ripeners than the latter two. It may, however, be stated here that this fact refers to total tillering of the plants and not to the effective tillering which makes up the major portion of the crop. These differences were found significant. The analysis further revealed that varieties in general had a larger number of healthier stalks than diseased ones and taken together for the varieties the difference between the two was significant at P =0·05, as is indicated by the significant value of the interaction between varieties and the healthiness of the stalks. Again diseased stalks less often matured than the healthy ones. This was particularly so of those that were damaged early in the season. It will be noticed that except the first order interaction between varieties and the mature versus immature stalks, the other interactions amongst all the three factors were significant.

Table X

Underground branching data—medium-early varieties

Varieties	Serial No.	Mature shoots								Immature shoots								Total shoots		
		Healthy				Diseased or damaged				Healthy				Diseased or damaged				Healthy	Diseased or damaged	Grand Total
		a	b	c	d&e	a	b	c	d&e	a	b	c	d&e	a	b	c	d&e			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Co 312	I	1	3	..	..	..	..	..	..	..	3	..	..	..	..	..	..	7	..	7
	II	1	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4	..	4
	III	1	3	..	..	..	..	..	..	..	1	1	..	..	..	..	..	6	..	6
	IV	1	5	3	..	..	..	..	..	..	..	2	..	..	1	4	..	11	5	16
	V	1	1	..	..	..	..	..	..	..	..	..	..	..	2	..	..	2	2	4
	VI	1	4	..	..	..	1	..	..	..	3	..	..	..	..	..	..	8	1	9
	VII	1	2	..	..	..	2	..	..	..	..	..	..	..	1	..	..	3	3	6
	VIII	1	5	..	..	..	..	..	..	..	..	3	..	..	1	..	..	9	1	10
	IX	1	5	1	..	..	..	..	..	..	..	..	..	..	1	2	..	7	3	10
	X	1	3	..	..	..	..	..	..	..	..	..	..	..	3	4	..	4	7	11
Total		10	34	4	..	..	3	..	..	..	7	6	..	..	9	10	..	61	22	83
Co 299	I	1	5	3	..	..	..	..	..	..	..	..	..	..	2	3	..	9	5	14
	II	1	8	5	..	..	..	..	..	..	..	..	..	..	..	6	..	14	6	20
	III	1	3	..	..	..	..	..	..	..	..	..	..	..	2	..	..	4	2	6
	IV	1	4	3	..	..	..	..	..	..	..	..	..	..	6	2	..	8	8	16
	V	..	7	5	..	..	..	..	..	..	..	..	..	..	5	7	..	12	12	25
	VI	1	3	..	..	..	..	..	..	..	..	..	..	..	3	2	..	4	5	9
	VII	1	5	..	..	..	..	..	..	..	..	..	..	..	2	..	..	6	2	9
	VIII	1	2	5	..	..	..	..	..	..	..	..	..	..	4	12	1	8	17	25
	IX	1	4	1	..	..	2	1	..	..	..	..	..	..	3	3	..	6	5	11
	X	1	3	1	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..
Total		9	44	23	..	..	2	1	..	..	..	..	..	..	28	36	1	71	63	135

TABLE X—*contd.*

Underground branching data—medium-early varieties—contd.

Varieties	Serial No.	Mature shoots								Immature shoots								Total shoots		
		Healthy				Diseased or damaged				Healthy				Diseased or damaged				Healthy	Diseased or damaged	Grand Total
		a	b	c	d&e	a	b	c	d&e	a	b	c	d&e	a	b	c	d&e			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Co 281	I	..	1	..	..	1	2	..	..	..	..	..	..	..	..	7	..	1	10	11
	II	1	4	..	..	..	1	..	..	..	..	..	..	..	..	2	..	5	3	8
	III	1	..	1	..	..	1	..	..	..	..	..	..	..	..	..	..	2	1	3
	IV	1	5	2	..	..	..	..	..	..	..	1	..	..	..	2	..	9	2	11
	V	..	3	1	..	..	..	..	..	..	..	..	..	1	2	8	..	4	11	15
Total		3	13	4	..	1	4	..	..	..	..	1	..	1	2	19	..	21	27	48
Co 427	I	1	5	..	..	..	..	..	..	..	..	3	..	..	1	..	..	9	1	10
	II	1	6	1	..	..	..	..	..	..	..	6	..	..	1	..	..	14	1	15
	III	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	2
	IV	1	3	1	..	..	..	..	..	..	..	1	..	..	1	..	..	6	1	7
	V	1	4	..	..	..	..	..	..	..	..	..	..	..	1	..	..	5	1	6
	VI	1	6	1	..	..	..	..	..	..	..	..	..	..	..	..	..	8	..	8
	VII	..	3	..	..	..	..	..	..	1	..	..	..	..	..	..	..	4	..	4
	VIII	..	4	..	..	1	..	..	..	..	1	..	..	..	2	..	..	5	3	8
	IX	1	5	2	..	..	..	..	..	..	2	..	..	..	1	..	..	10	1	11
	X	..	5	..	..	1	..	..	..	..	..	..	..	..	..	..	..	5	1	6
Total		6	42	6	..	2	..	..	..	1	3	10	..	..	7	..	..	68	9	77
Co 313	I	1	7	..	..	..	..	..	..	..	1	5	..	..	1	..	..	14	1	15
	II	1	5	1	..	..	..	..	..	..	1	7	..	1	..	..	..	15	..	15
	III	..	4	3	..	..	..	..	..	..	2	..	..	1	1	..	..	9	2	11
	IV	..	1	..	..	..	..	..	..	..	..	..	..	1	1	1	..	1	3	4
	V	1	5	4	..	..	..	..	..	..	2	2	..	..	..	1	..	14	1	15
	VI	1	4	1	..	..	..	..	..	..	1	..	..	..	..	1	..	7	1	8
	VII	1	6	..	..	..	..	..	..	..	..	3	..	..	1	2	..	10	3	13
	VIII	..	5	..	..	..	..	..	..	..	..	2	..	1	3	..	..	7	4	11
	IX	1	3	3	..	..	..	..	..	..	..	1	..	..	4	2	..	8	6	14
	X	..	3	1	..	..	..	..	..	..	..	..	..	..	..	9	..	4	9	13
Total		6	43	13	..	..	..	..	..	..	7	20	..	3	11	16	..	89	30	119
Co 549	I	1	5	6	..	..	..	..	..	..	..	..	2	..	1	..	..	14	1	15
	II	1	3	2	..	..	1	..	..	..	..	..	..	..	1	1	..	6	3	9
	III	1	2	..	..	..	..	..	..	..	..	..	..	..	1	..	..	3	1	4
	IV	..	3	2	1	1	1	..	..	..	..	..	..	..	3	..	..	6	5	11
	V	..	5	3	..	..	..	..	..	..	..	2	2	..	2	..	..	12	2	14
	VI	1	6	6	..	..	..	..	..	..	..	1	..	..	8	3	..	14	11	25
	VII	1	6	2	..	..	1	..	..	..	..	..	..	..	2	2	..	9	5	14
	VIII	1	3	2	..	..	..	..	..	..	..	..	..	..	..	2	..	6	2	8
	IX	..	4	3	..	1	..	..	..	..	..	..	..	..	..	2	..	7	3	10
	X	1	6	..	..	..	..	..	..	..	..	..	..	..	2	2	..	7	4	11
Total		7	43	26	1	2	3	..	..	..	..	3	4	..	20	12	..	84	37	121

TABLE XI

Analysis of variance

Underground tillering data—medium-early varieties

Due to	D.F.	Sum of squares	Mean variance	V_1/V_2
Blocks	9	50·62	5·62	..
Varieties (V)	4	79·22	19·81	6·42**
Maturity of stalks (M)	1	67·28	67·28	21·82**
Healthiness of stalks (H)	1	224·42	224·42	72·88
Interactions :—				
V X M	4	24·72	6·03	1·96
V X H	4	44·18	11·04	3·58*
M X H	1	784·04	784·08	254·28**
V X M X H	4	432·82	108·21	35·09**
Residual error	171	527·28	3·08	

Standard error=$\pm$1·755 *Indicates significance at 5 per cent **Indicates significance at 1 per cent

Mid-season varieties. A perusal of Table XII will show some broad outstanding facts. For instance the major portion of the crop was formed of the 'b' shoots together with 'c' shoots in a few cases. Again 'c' shoots were the very shoots of which a large proportion remained immature because of the attack of pests, diseases and other physiological causes. Larger was the production of these two types of shoots, greater was the proportionate mortality in the varieties. Next, the varieties such as Co331, Co419 and Co451, possessing high yielding power, did not necessarily have a larger number of total tillers produced by the plants, other factors contributed potently to increase the yield, e.g. high germinability of varieties, thickness of stalks, etc. From the table of analysis of variance (Table XIII) it would be observed that the varieties differed widely in their underground branching. The varieties Co290 and Co312 had developed significantly greater number of underground branches than rest of the varieties. Again the varieties Co438, Co534 and Co451 had significantly a larger number of shoots than either Co331 or Co419. Secondly in general, the number

TABLE XII

Underground branching data—Mid-season series

Variety	Serial No.	Mature shoots								Immature shoots								Total shoots		
		Healthy				Diseased or damaged				Healthy				Diseased or damaged				Healthy	Diseased or damaged	Grand Total
		a	b	c	d&e	a	b	c	d&e	a	b	c	d&e	a	b	c	d&e			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Co 290 . .	I	..	6	2	..	..	..	..	..	..	1	1	..	1	..	..	..	10	1	11
	II	..	2	11	3	..	..	..	..	..	..	..	..	..	2	3	6	16	11	27
	III	1	4	7	3	..	..	1	..	..	..	..	..	..	1	5	5	15	12	27
	IV	1	2	5	3	..	..	..	..	..	..	..	1	..	..	2	..	12	2	14
	V	1	8	3	..	..	..	..	..	..	..	..	..	..	1	8	1	12	10	22
	VI	1	2	12	5	..	..	..	..	..	..	..	..	..	1	4	..	20	13	33
	VII	1	7	6	..	..	..	..	..	..	..	1	..	..	1	..	..	15	1	16
	VIII	1	5	2	..	..	..	..	..	..	..	..	..	..	..	2	..	8	2	10
	IX	1	3	3	..	..	..	..	..	..	..	..	..	..	1	..	5	7	6	18

TABLE XII—*contd.*

Underground branching data—Mid-season series—contd.

Variety	Serial No.	Mature shoots								Immature shoots								Total shoots		
		Healthy				Diseased or damaged				Healthy				Diseased or damaged				Healthy	Diseased or damaged	Grand Total
		a	b	c	d & e	a	b	c	d & e	a	b	c	d & e	a	b	c	d & e			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Co 312	I	1	2	5	..	..	..	..		..	..	..	..	..	4	1	2	8	7	15
	II	..	5	10	5	..	..	..	..	..	..	..	5	..	..	9	7	25	16	41
	III	1	6	2	..	..	..	..	..	..	..	..	3	1	6	..	..	12	7	19
	IV	1	6	9	..	..	..	..	..	..	..	4	2	..	1	1	1	22	3	25
	V	1	8	4	..	..	..	..	..	..	..	2	..	..	..	1	..	15	1	16
	VI	1	7	3	..	..	..	..	..	..	..	..	..	..	1	2	2	11	5	16
	VII	1	3	1	..	..	..	..	..	..	..	..	..	..	..	2	..	5	2	7
	VIII	1	3	2	..	..	..	..	..	..	..	..	..	..	1	4	1	6	6	12
	IX	1	8	3	2	..	..	..	..	..	..	3	..	..	1	5	..	17	6	23
Co 331	I	1	1	..	..	..	..	..	..	..	..	2	..	..	1	..	..	2	1	3
	II	1	2	..	..		..	..	..	..	..	3	..	..	2	..	..	6	2	8
	III	1	3	..	..	..	..	..	..	..	..	..	..	..	1	..	..	4	1	5
	IV	1	2	..	..	..		..	..	..	..	..	..	..	4	3	..	3	7	10
	V	..	3	..	..	1	..	..	..	..	..	..	..	..	3	..	..	3	4	7
	VI	1	3	..	..	..	1	..	..	..	..	..	..	..	2	3	..	4	6	10
	VII	1	3	..	..	..	..	..	..	..	..	..	..	..	3	3	..	4	6	10
	VIII	1	3	1	..	..	..	..	..	..	..	..	2	..	..	4	..	7	4	11
	IX	1	2	..	..	..	..	..	..	..	..	..	..	..	3	..	..	3	3	6
Co 419	I	1	2	..	..	..	..	..	..	..	..	..	..	..	1	..	..	3	1	4
	II	1	2	..	..	..	..	..	..	..	..	..	..	..	2	..	..	3	2	5
	III	..	3	..	..	..	..	..	..	..	..	..	..	1	3	..	..	3	4	7
	IV	..	3	1	..	1	..	..	..	..	..	..	..	..	2	2	..	4	5	9
	V	1	1	1	..	..	..	..	..	..	..	..	..	..	..	3	..	3	3	6
	VI	1	1	..	..	..	..	..	..	..	..	..	..	..	1	..	..	1	2	3
	VII	..	1	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1	1	2
	VIII	..	3	4	..	..	..	..	..	..	..	..	..	1	1	2	..	7	4	11
	IX	1	3	..	..	..	..	..	..	..	..	..	..	..	..	2	..	4	2	6
Co 438	I	1	6	7	1	..	..	..	..	..	..	..	..	..	2	2	1	15	5	20
	II	1	10	2	..	..	..	..	..	..	..	..	..	..	2	4	..	13	6	19
	III	..	3	3	..	..	..	..	..	..	..		..	..	4	2	..	6	6	12
	IV	..	6	4	..	..	..	..	..	..	..	..	..	..	3	1	..	10	4	14
	V	..	3	2	..	..	..	..	..	..	..	..	..	..	4	3	..	5	7	12
	VI	..	2	5	1	..	..	..	..	..	..	..	..	..	1	9	5	8	15	23
	VII	1	6	2	..	..	..	..	..	..	..	..	..	..	2	..	..	9	2	11
	VIII	1	9	7	1	..	..	..	..	..	..	..	..	..	1	3	2	18	6	24
	IX	1	4	2	..	..	1	..	..	..	..	..	..	..	6	1	..	7	8	15

TABLE XII—*concld.*

Underground branching data—Mid-season series—concld.

Variety	Serial No.	Mature shoots								Immature shoots								Total shoots		
		Healthy				Diseased or damaged				Healthy				Diseased or damaged				Healthy	Diseased or damaged	Grand Total
		a	b	c	d & e	a	b	c	d & e	a	b	c	d & e	a	b	c	d & e			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Co 451	I	1	7	1	..	..	..	..	..	..	..	..	..	..	4	3	..	9	7	16
	II	1	5	..	..	..	..	2	..	..	..	..	..	..	..	5	..	6	7	13
	III	1	2	..	..	..	..	2	..	..	..	..	..	..	4	2	..	3	8	11
	IV	1	4	1	..	..	..	..	..	..	..	..	..	..	2	5	1	6	8	14
	V	1	3	1	..	..	1	..	..	..	3	..	..	..	6	6	..	8	13	21
	VI	1	3	1	..	..	..	..	..	..	..	..	..	..	2	5	..	5	7	12
	VII	1	4	..	..	..	..	..	..	..	..	..	..	..	..	8	..	5	8	13
	VIII	1	1	..	..	..	..	2	1	..	2	1	..	..	3	2	1	5	9	14
	IX	1	3	..	..	..	..	..	..	..	..	..	..	..	4	6	..	4	10	14
Co 534	I	1	7	4	..	1	..	..	..	..	6	..	..	..	..	10	..	19	11	30
	II	..	3	1	1	2	..	..	..	..	..	..	..	2	3	2	..	4	8	12
	III	..	5	5	1	1	..	..	..	..	..	..	..	..	..	4	..	10	6	16
	IV	1	3	6	..	..	..	..	..	6	..	..	..	..	4	1	4	16	9	25
	V	1	4	2	..	..	..	..	..	..	..	..	..	..	4	5	..	7	9	16
	VI	1	4	3	..	..	..	..	..	..	..	..	..	..	3	7	..	8	10	18
	VII	1	3	1	..	..	..	..	..	..	4	..	..	..	4	4	..	9	8	17
	VIII	1	2	..	..	..	..	..	..	..	..	..	..	..	1	..	..	3	1	4
	IX	1	3	2	..	..	..	..	..	..	..	..	..	..	2	2	..	6	4	10

TABLE XIII

Analysis of variance

Underground tillering data—Mid-season series

Due to	D.F.	Sum of squares	Mean of variance	V_1/V_2
Blocks	8	68·58	8·57	..
Varieties (V)	6	389·28	64·88	9·92**
Maturity of stalks (M)	1	47·78	47·78	7·32**
Healthiness of stalks (H)	1	96·57	96·57	14·76**
Interactions :—				
V X H	6	177·88	29·65	4·53*
M X V	6	158·17	26·36	4·03*
M X H	1	2198·58	2198·58	335·99**
H X M X V	6	277·97	46·33	7·08**
Residual error	216	1412·64	6·54	

Standard error = ± 2·55 *Indicates significance at 5 per cent **Indicates significance at 1 per cent

of mature stalks was significantly larger than immature stalks. Thirdly, healthy stalks were significantly greater than the stalks which remained undeveloped due to diseases, pests or physiological causes. Fourthly, interaction between varieties and mature versus immature stalks was significant indicating that though varieties in general had a larger number of mature stalks than immature stalks, the varieties Co331, Co451 and Co534, differed from this general behaviour. They had slightly larger number of immature stalks than mature stalks. Fifthly, the interaction mature versus

immature and healthy versus diseased stalks—was very highly significant. Matured stalks had a very high percentage of healthy stalks while in the immature stalks the number of diseased canes were proportionately high. Lastly, the second order interaction- varieties X mature versus immature X healthy versus diseased stalks—was also significant.

Millable cane values of varieties

The mature stalks in the underground branching series were measured separately in both the trials, namely, medium-early and mid-season series. The data are given in Table XIV.

Table XIV

Millable cane values : (A—Medium-early series ; B —Mid-season series)

Series	Varieties	Mean cane weight in cm.	Mean cane length in cm.	Weight per unit length in cm.	Mean cane girth in cm.	Cane module value
A Series	Co312	581·7±85·4	188·5±51·2	3·09	6·9±0·87	86
	Co281	439·2±135·4	135·7±118·9	3·24	6·1±2·82	70
	Co299	524·0±160·3	184·3±36·5	2·84	5·4±1·66	107
	Co313	580·7±234·5	165·1±47·8	3·51	6·1±2·56	84
	Co427	732·9±237·4	202·3±86·9	3·62	7·8±0·22	82
	Co549	510·9±248·2	180·0±57·9	2·84	4·5±0·96	125
B Series	Co290	590·0±98·2	158·9±72·2	3·72	7·2±1·30	70
	Co312	631·6±257·5	172·2±73·6	3·66	7·0±1·32	78
	Co331	669·4±305·3	185·9±51·1	3·61	7·4±1·03	80
	Co419	1196·0±322·7	214·4±78·5	5·58	8·4±1·50	81
	Co438	601·7±238·5	186·7±50·2	3·22	6·4±0·90	93
	Co451	635·4±347·0	200·3±62·1	3·17	6·3±1·30	101
	Co534	613·0±292·2	166·2±42·0	3·69	6·8±1·80	78

It will be noted that varieties, in general, showed wide variations in the weight of the stalks, as is indicated by the high level of variation shown by them. Mean stalk length of varieties amongst themselves also exhibited conspicuous differences. In mean cane length of stalks the varieties individually showed as high a degree of variation as in cane stalk weight. Variety Co281 particularly had a remarkable variation in this respect. The range of variation in the medium-early varieties between minimum stalk length of Co281 and the maximum stalk length of the variety Co427 was 66·6 cm. In the mid-season series such a variation in the cane length amongst the varieties was 55·5 cm. Similar variation was noticed in mean cane girth of varieties in both the varietal series.

In the last column of Table XIV are given the cane module values for the varieties. The variation in the cane module values is as high as in the other millable cane characters of the varieties. One thing more is evident— the cane module values for a ten months crop of Sunnabile or Saretha group canes at Coimbatore were higher than crop of the same age in this province, although these groups are definitely less vigorous than the Co-cane [Barber, 1918] varieties.

In both the trials the standard cane variety was Co312. In the mid-season trial the weight per unit length of cane was higher than in the medium-early series. Now medium-early experiment was planted on light loam soil and was cropped in *Shaftal* (*Trifolium rasupinatum*) so that the land received no preliminary cultivation. The crop had an average stand. On the other hand, mid-season trial had been planted on well manured land which had received good cultivation. It appears probable that, as a consequence of this, a higher weight per unit length was obtained in the mid-season series as compared to the medium-early series. This point has been mentioned as a preliminary observation which requires confirmation by extensive study.

Significance of results

In the preceding text we have presented results of growth measurements of varieties in trials conducted during the years 1940 to 1944. For each of the varietal trials growth data have been presented as (a) cummulative growth in length, to indicate differences in the absolute growth of the

varieties and (b) exponential height growth curves, to describe difference in parameters A and B of the varieties in different crop seasons and to correlate the derived parameters with mean yield of varieties and their mean sucrose content in juice. Besides, (c) correlations between the efficiency indices of growth and the mean daily growth rates of varieties in different trials have been worked out to show the relationship between these two parameters. In prospecting yields, the importance of the study of formative growth values and millable cane characters is quite obvious. These characters were studied in the year 1942-1943 in both the medium-early and mid-season series. Collectively all these investigations throw some light on cane growth and functions associated with it.

Growth relative to environment. It is a patent fact that environment as well as inherited differences affect the behaviour of the same variety in different years. Besides the inherent differences in the nature of the protoplasm, other internal factors such as osmotic concentration of cell sap, number and size of growing points and the relative availability of manufactured food are some of the factors which determine growth. These factors may be markedly altered by the external conditions and according to Briggs [1928] and Gregory [1928] the external conditions merely accelerate or retard the way in which the internal factors such as temperature light, moisture, electricity and the amount and composition of the materials in the soil influence growth. Of these temperature is by far of greater importance than other environmental factors. Miller [1938] states, " In general, the growth curve in relation to temperature shows three cardinal points, the minium, the lowest temperature at which growth is exhibited ; the optimum, the temperature at which growth is the greatest ; and the maximum, the highest temperature at which growth will occur. "Optimum temperature means favourable conditions for assimilation and growth during the day time. Das [1933] has taken 70°F. as the threshold value for the optimum temperatures. The temperature values above this limit have been termed as day degrees. Comparable results for two years of the varietal trials are available for comparison and for a study of the influence of day degrees on growth of the crop. These results are presented in Table XV.

TABLE XV

Initial growth in relation to day degrees (A— growth in cm. ; B— day degrees.)

Year	Particulars of experiment	Growth in different months						Mean parameter A values
		April		May		June		
		A	B	A	B	A	B	
1941—1942	Medium-early	9·42	+21·2	9·43	+29·3	28·32	+37·6	9·243
1942—1943	Medium-early	7·00	+19·3	7·21	+27·7	14·16	+32·5	2·725
1941—1942	Mid-season	8·09	+21·2	10·75	+29·3	24·75	+37·6	7·21
1942—1943	Mid-season	6·95	+19·3	7·55	+27·7	17·64	+32·5	5·80

Approximately in 1941-1942 the day degrees were higher by two units per day (+60 F. per month) for the months of April and May and about five units higher for the month of June (+150°F.) compared to 1942-1943 and the influence of these differences is marked on the development of varieties both in the medium-early and mid-season series. This effect is particularly in evidence in the growth accumulated in the months of June when the cumulative effect of temperature was manifested more pronouncedly than that in the preceding months. The medium-early varieties comparatively suffered less than mid-season canes. The comparable elongation in April and May was also less. The parameter *A* of the exponential height growth curves in the two varietal trials in the two years indicated differences of the similar type as in the monthly growth accumulations noted above. These comparable data do bring out somewhat in relief the influence of day degrees on early growth of the crop and confirm the conclusions of Das [1933] and Shaw and Sweezy [1937] that day degrees bear a relationship to the growth of the crop. Agee [1930] and Summerville [1944]

have suggested that the growth made is actually represented about a month after it had set in. Assuming that to be the position the difference in mean growth represented in June should be attributable to April and to May temperatures. It is thus probable that low day degrees in April and May more affected the accumulation of growth in June, when the elongation process could also show marked differences, than in the values for May or April themselves. Apparently maximum temperatures above 70°F. very vitally influence the elongation process in the plants.

Cumulative growth in length. Differences in the cumulative growth amongst the varieties in every trial and in each one of the years are more clearly apparent in sigmois curves draw and represented in Fig. 1. The general analysis of the data is given in Table XVII.

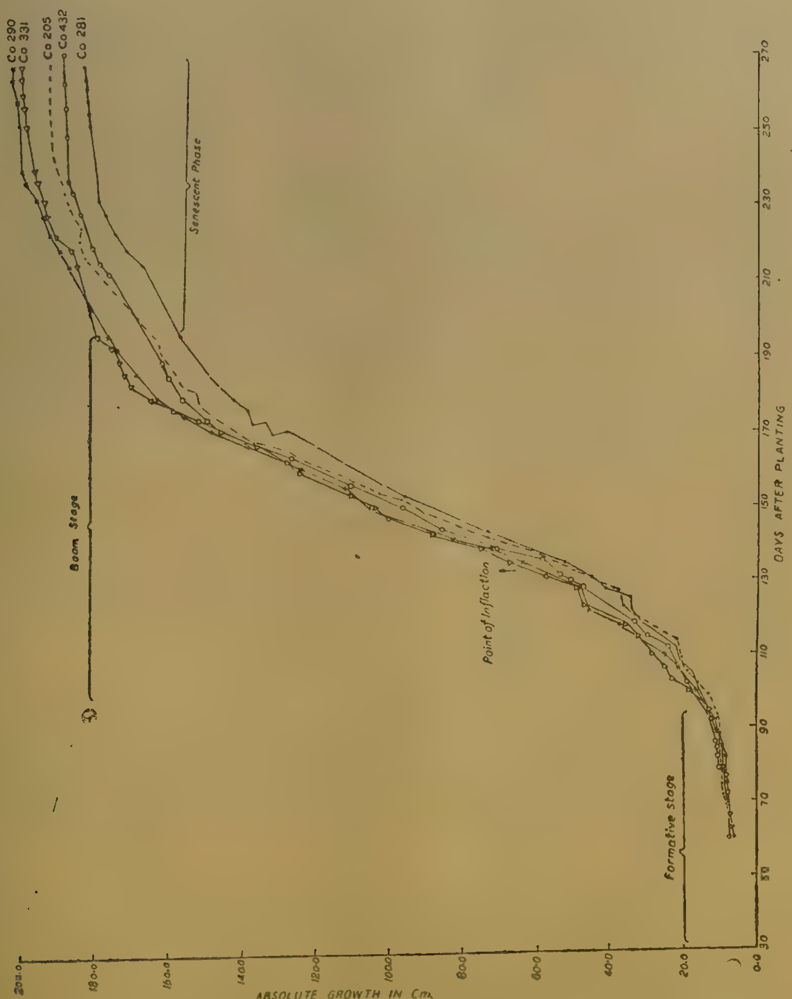

Fig. 1. Cumulative growth curves.

TABLE XVI

Differences in cumulative growth : A—Days in formative, boom and senescent phases ; B—Approximate mean growth in cm.

Year	Name of trial	Nature of crop	Period of growth						Total	
			Formative		Boom		Senescent			
			A	B	A	B	A	B	A	B
1940—1941	Physiological	Plant	95	13	100	152	50	21	245	186
1941—1942	Medium-early	Plant	70	19	130	216	45	50	245	275
1941—1942	Mid-season	Plant	45	13	150	217	50	22	245	242
1942—1943	Medium-early	Plant	130	18	90	139	25	12	245	169
1942—1943	Mid-season	Plant	80	18	100	146	65	13	245	177
1942—1943	Mid-season	Ratoon	120	18	140	221	50	13	310	252
1943—1944	Medium-early	Ratoon	110	21	100	125	70	13	280	159
1943—1944	Mid-season	Plant	85	13	110	148	50	70	245	268

In the preceding section it has been pointed out that season in 1941-1942 was more favourable than in 1942-1943 for the early development of the crop in the medium-early and mid-season series. The data presented in Table XVI indicates that while in 1941-1942 the formative period for the medium-early and the mid-season series comprised of 70 and 45 days respectively, it took 130 and 80 days to complete the process in 1942-43. Therefore, the 'grand period of growth' extended over a longer period in the former season than in the latter year. Shortness of the elongation period in the boom stage considerably reflected in the growth accumulated. While in 1941-1942 the growth put on was 216 and 207 cm. by the medium-early and the mid-season series, in 1942-1943 it was 139 and 146 cm. respectively. The growth in height of the plants was reduced not only in the boom stage but also in the senescent stage of the crop. The growth made respectively was 50 and 22 cm. in the former and 12 and 13 cm. in the latter year.

In the same year, i.e. 1942-1943, the crop growth during the formative period was similar, but the boom stage being longer in the ratoon than in the plant crop, the former crop in the grand growth stage accumulated more growth than the ratoon crop. The results of the medium-early ratoon crop give added support to the above results in this respect. Here the period of elongation was limited to 100 days only and therefore, the actual growth put on was 125 cm. only.

Thus in the process of growth a time factor may operate to limit the elongation of cells during the grand period stage of the crop. 'This ability to grow rapidly is a distinct advantage to an organism where there is a time limit to its period of growth' [Miller, 1938].

Exponential height growth curves and performance of varieties. Priestley [1929] distinguishes three stages in the growth of cells, namely, (a) embryonic or formative stage, (b) the stage of elongation, and (c) the stage of differentiation. Differentiation according to Loomis [1932] is the sum of the morphological changes that start during cell enlargement and end with the death of the cell. A cell after differentiation solely functions for helping other cells to grow and develop. After the maximal enlargement of the cell has taken place, it tends to become a specialized cell, e.g. a sieve tube, a trachied, etc. A specialized cell invariably continues to be what shape it attains after maximal enlargement.

Analogous three stages of development are observed in each plant part or organ. Thus each organ has its formative stage, grand growth (elongation) stage and its stage of differentiation or maturition. The elongation of any part begins at a slow rate that gradually increases to a maximum after which the rate progressively falls off until enlargement ceases. The embryonic stage commingles with the rate of development in the initial stages of plant life and the stage of maturition or differentiation with the progressively decreasing rate of elongation of plant organs. These three stages have been distinctly indicated by the cumulative growth in length curves of the varieties in the experiments described above (Fig. 1).

MacDougal [1916, 1921] from his extensive studies concluded that in the formative period before cells divide they increase in volume by the protoplasmic hydration. This stage he called acceration stage of the cells. During this stage, proteins and carbohyderates are formed by synthesis, dehydration and condensation [MacDougal, 1925]. When the mass of a cell reaches a certain point, cell division begins.

In these cells protein synthesis is dominant, while carbohydrate metabolism and storage is at its minimum. After the cell has been formed it needs to strengthen its cell wall which may stand the stress of increasing turgor. Therefore the protoplasm after the formation of new cells tends towards carbohydrate synthesis rather than protein synthesis [Priestley, 1928, 1929]. MacDougal [1919], in the leaves of *Crassulaceae*, in the joints of cacti and in fruits, observed little increase of dry matter, although growth as measured by the change in form was recorded. The proportion of water and solid matter thus underwent but little change. Freeland [1933] observed in *Bryophyllum* that osmotic pressure of the margins of the proliferating leaves was in general higher than that of the paired, inactive leaves. By this osmotic action the volume of the plant cell increases several hundred times and yet contains very little extra protoplasm than before expansion began. This occurs without the expenditure of energy necessary to manufacture relatively large quantities of protoplasm.

In the preceding section comparative exponential height growth curve values of varieties in the eight trials have been given in Tables I, II and VI. The exploratory correlations worked out have shown that although the value of initial rapidity of growth (*A* value) are correlated positively with the cane yield in all the eight trials, the extent of correlations is low and non-significant in all except two cases in which the significance of the coefficients between the two was high (Table XVII). This indicates that the initial rapidity of growth possessed by the varieties is not the chief factor on which the yield depends, other factors also modify the yield of the crop.

Also from the above quoted evidence it may be observed that as cell division and protein synthesis chiefly take place during the embryonic or early growth of the crop and in the rapid elongation process the protein synthesis takes place at a low rate, early growth or initial potential of growth must influence a good deal the total likely growth to be made by the plant, for, however favourable the environment in the rapid elongation period may be, the growth must be limited by the embryonic outlay in the plant in the formative stage.

TABLE XVII

Summarized correlation coefficients

Year	Nature of the trial	Nature of the crop	Correlation coefficient: Between *A* and mean yields	Correlation coefficient: Between *b* value and mean sucrose per cent
1940—1941	Physiological	Plant	+0·28	+0·98***
1941—1942	Medium-early	,,	+0·326	+0·926***
1941—1942	Mid-season	,,	+0·41	+0·593
1942—1943	Medium-early	,,	+0·818**	+0·915***
1942—1943	Mid-season	,,	+0·382	+0·713*
1942—1943	Mid-season	Ratoon	+0·536	+0·933***
1943—1944	Medium-early	,,	+0·556	+0·711*
1943—1944	Mid-season	Plant	+0·817**	+0·785*

***Indicates significance at $P=0·01$ **Indicate significance at $P=0·05$ *Indicates significance at $P=0·10$

In other words with limited number of cells formed in the initial stage of plant life, however rapid and large the distension of cells may be, the total mass of tissues would remain small. Varieties possessing high initial rapidity of growth or *A* value generally have been observed to yield more than with low *A* value.

The correlation coefficient values between parameter b and mean sucrose percentage in the juice over the crushing season were significant in seven out of eight trials. This indicates that the study of b values have shown more intrinsic value than that postulated by Blackman [1919]. He simply referred to the rate of production of dry matter, while our studies show that a variety may, by virtue of its initial rapidity of growth, gain advantage and produce a larger amount of dry matter, but it may not have a large b value or relative growth rate of the crop, which in sugar cane indicates better sugar accumulating power in the plant.

The values of the relative growth rate of varieties in the two trials over the entire period of study extending over three years are shown in Table XVIII. The differences in each of the trials in respect of the b values of the varieties have already been explained. We discuss them from another aspect here. Briefly, it will be noted that in both the years in the medium-early trial variety Co281 had the highest value of b and Co312 the lowest: other varieties occupied, with slight variations, a mid-position between the two. Similarly in the mid-season trial Co534 had the highest position in respect of b values in all the years, other varieties indicated small differences amongst themselves. Broadly speaking, then, the varieties maintained a similar level of efficiency of growth in the different years. Summerville [1914] considers this to be conferred by the genetical constitution of the varieties.

TABLE XVIII

Value of b *in different years in plant crop*

Nature of experiment	Variety	1941-1942	1942-1943	1943-1944
Medium-early series	Co312	0·01433	0·01284	
	Co281	0·01785	0·01848	
	Co299	0·01595	0·01842	
	Co313	0·01643	0·01786	
	Co427	0·01556	0·01653	
	Co549	0·01544	0·01829	
Mid-season series	Co290	0·01687	0·01686	0·01499
	Co312	0·01598	0·01677	0·01323
	Co331	0·01472	0·01744	0·01343
	Co419	0·01809	0·01885	0·01399
	Co438	0·01739	0·01742	0·01454
	Co451	0·01759	0·01537	0·01455
	Co534	0·01824	0·01948	0·02181

In Table XIX are given the comparative data for the plant and ratoon crops of the mid-season series to show that by ratooning both b and A parameters are modified for instance.

TABLE XIX

Mid-season series—plant versus ratoon crop 1942-1943

Comparison of parameters A *and* b *with acre yields and mean sucrose percentage in juice*

Variety	Plant: Parameter A value	Plant: Mean yield in md.	Ratoon: Parameter A value	Ratoon: Mean yield in md.	Plant: Parameter b value	Plant: Mean percentage of sucrose	Ratoon: Parameter b value	Ratoon: Mean percentage of sucrose
Co290	6·91	375	5·96	669	0·01686	12·12	0·01396	11·50
Co312	5·83	457	4·19	744	0·01677	11·47	0·01474	12·37
Co331	7·56	339	5·00	1012	0·01744	12·58	0·01532	12·18
Co419	4·53	182	3·18	709	0·01885	12·62	0·01639	12·12
Co438	5·46	429	3·04	529	0·01742	11·73	0·01639	11·91
Co451	6·55	272	0·68	644	0·01537	12·04	0·02393	13·55
Co534	3·76	272	1·25	537	0·01948	13·11	0·02181	13·18
Value of r=		+0·382		+0·536		+0·713*		+0·933***

Co451 behaved rather in an interesting manner. In spite of its maintaining a high yield level, almost equal to Co290 in the ratoon crop, it developed more sugar in juice than the latter. The accumulation of high sugar was a consequence of the high efficiency of growth of the crop under consideration. On the contrary, Co331 developed more in yield in ratooning and its efficiency index was lowered and a corresponding fall in sugar content of the juice was noticed. Evidently when the plant has a tendency to develop mass, it diverts its sugar for synthesis into cellulose and in effect the sugar accumulation suffers, which is indicated by a low growth efficiency of the crop. On the contrary, when there is a tendency to accumulate sugar, the crop tends to depress its yield, for its sugar does not transform into larger amount of cellulose which may allow greater distension in the cells. The ratoon crop obtains advantage of the time factor. Therefore, given the initial requirements of mineral matter, under favourable environment, not only the ratoon crop of the variety is able to accumulate greater growth in stalk length but develop a greater relative growth rate generally, unless there is something genetically inhibiting in the variety, and thus accumulate more sugar in the plant.

Interrelationship between A *and* b *values and its interpretation.* In general the data given in Tables I, III and VI revealed that when a variety indicated high initial rapidity of growth, it very often possessed low efficiency index value and vice versa. This fact was found to hold good in all the four years in which eight trials had been conducted. The probable explanation for it appears to be that when protein synthesis is active, meristem forms quickly and its outlay is greater and, in consequence, when the elongation process starts, meristem elongates in proportion, unless the plant suffers from water shortage to the total outlay of the meristem. The sugars in that period instead of accumulating are utilized for greater cellulose formation, to strengthen the distending cell walls and not stored as saccharose in the cane stem. On the other hand, when the meristem developed in the embryonic stage is small, the total elongation that can take place is small and a small amount of hexoses is comparatively required for the formation of cellulose. When the maximum requirement of cellulose for the fewer number of cells is satisfied the remaining sugars are accumulated in the form of cane sugar in the cane stem. As such, it is observed, that when A value, or the initial rapidity of growth, is high in a variety, its corresponding b value is low and vice versa.

Underground branching differences in varieties. In both the varietal trials, namely, medium-early and the mid-season series, very wide differences in tillering were observed amongst the varieties. Varieties with larger number of tillers matured earlier than others only in the former trial. This partially, confirms the findings of Barber [1919]. Again, in both the trials varieties generally developed, in the absence of any epidemic, more healthy shoots than those showing mortality. Thus the proportion of the matured stalks was larger than immature stalks. It was also noticed that the major portion of the millable canes was formed of the mother shoots together with b type of shoots or shoots of the second order and it is these shoots which should be encouraged in the season to contribute towards greater yield of the crop. Besides the mother shoots, second order shoots are the first to appear and since it is these which need encouragement it will not be too much to presume that the crop manuring is indicated early in the season in this tract and should be applied in time to induce their rapid growth. Late manuring is likely to encourage greater production of c type of shoots which as we have noticed, remain immature or die prematurely. This happens, as Barber [1919] has pointed out, because of the lack of light space by which late developed shoots get at a disadvantage as they are overshadowed by their neighbours. He goes on to state, 'It is fairly certain that this death of shoots is not due to lack of food supply in the soil, for this can and habitually is supposed to meet all possible needs.. Light is perhaps the most important limiting factor as regards tillering'. Besides the light factor, he has discussed the influence of soil moisture, manuring and spacing on tillering. He considers that these factors may limit tillering, they seldom cause high mortality under normal conditions.

Millable cane values of varieties and crop estimation. Varieties exhibited as large variations in millable cane characters as in their underground branching. These cane values point to the fact that where varieties have low germination or low tillering and the crop does not have a rapid initial start, the weight per unit length, height of the millable stalks, thickness of joints, etc., make up for the increase in the yield of the variety. The instance of variety Co419 may be cited in this

connection. This variety on the whole possesses a low tillering and a low A value, but this loss is made good by the larger girth of the cane and greater millable length of the stalks. Contrary to this, the yield in Co312 is made up by greater tillering of the crop and a high A value of growth than by the girth or length of the stalks. Thus it will be observed that though for a single variety crop estimation may be done by a simple formula as given by Shaw and Sweezy [1937], it is not possible to have a common formula when varieties differ in so many respects. It is, however, possible to find out partial regression equations between yield as the dependent variable and other contributing factors as the independent ones. Such derived equations for the varieties would illustrate the contribution of each growth factor to the yield of the varieties. The possibilities of this procedure are now being investigated.

Summary

The paper deals with four years' investigations on growth in length in the various trials. In the year 1941-1942 the underground branching and millable cane characters of varieties in two of the trials were also studied.

Varieties exhibited wide differences in all the eight trials in their cumulative growth data year after year amongst the various varieties. In years with short formative periods the grand growth period correspondingly increased, which helped the elongation process in cane stalks. The ratoon crop gained advantage over the plant crop in this manner end accumulated larger growth by harvest. Thus it is shown that where there is a time limit to the p riod of growth the ability to grow rapidly is a distinct advantage for the variety.

Varieties possessing high A values usually had low b values in the exponential height growth curves. The correlation coefficient values between the parameter b and mean sucrose percentage in juice over the entire ripening period. were significant in seven out of eight trials. The correlation values between A and the mean yield values of the varieties were low and significant in two out of eight trials only. Subject to environmental influences the varieties generally maintained a similar level of efficiency indices in the various years. This is presumed to be conferred by the genetical constitution of the varieties. Ratooning modified the efficiency indices and initial rapidity of growth values of the varieties. The significance of these results has been discussed in the paper.

Studies on underground branching of varieties indicated that most of the crop of millable stalks is formed of mother shoots together with shoots of the second order. Late formed shoots, principally composed of third order shoots, mostly remained immature or died prematurely. It is deduced from the results that early manuring will be helpful for inducing vigour in early formed tillers which mature into millable canes.

Millable cane characters such as weight per unit length of the stalk, girth of joint, etc., may be contributing factors towards yield of the varieties which possess low initial potential of growth and low tillering per clump. The estimation of crop yield, therefore, cannot be based on a simple formula as suggested by some of the Hawaiian workers. All these factors must be taken into account in working out partial regression equations of yield for the different varieties.

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STUDIES IN TILLERING AND ARROWING IN CO421 AT ANAKAPALLE*

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(With three text-figures)

Tillering and arrowing are two of the most important factors that influence yield in sugarcane. A variety which does not tiller well yields usually fewer canes per unit area and hence may record lower yields. Arrowing limits vegetative development and therefore the yield. Normally canes put forth arrows in October-November in these parts. Although the grand period of growth extends only from June to October, non-flowering canes put on growth to a smaller or greater extent even later on. This amount of cane growth will be lost to the cultivator if varieties arrow in October or November.

Several inherent and environmental factors affect tillering and arrowing. An experiment designed to study the influence of the age of shoots on their arrowing and juice quality was laid out at Anakapalle and was conducted for three consecutive years from 1940-1941 onwards. Information regarding tillering and incidence of shoot borers could also be gathered incidentally from this experiment and is presented below.

Material and methods

Sugarcane is generally planted in this station in the month of March. One budded sets of Co421 were planted ten inches apart in the row and 2 ft. 8 in. apart between rows in about 20 cents of land

*This formed part of the work which is being carried out at the Agricultural Research Station, Anakapalle, in the scheme partly financed by the Imperial Council of Agricultural Research. Salient features of this paper were published in the Annual Reports of this station.

Over a basal dressing of five tons of farm yard manure one hundred pounds of nitrogen was applied to this crop as a top-dressing in two equal doses at planting and trenching times respectively. In the matter of irrigation and other treatments the crop was treated just as any other normal crop on the station.

Plantings were done on the 5, 10 and 8 March during 1940-1941, 1941-1942 and 1942-1943 respectively. Starting from the 15 day after planting, about 1,000 plants were marked at random each year, by labelling them as shown in Fig. 1. After thus selecting 1,000 plants, tillers which arose from them were marked till the end of August at four day intervals in the same manner as the parent shoots. On each day of marking the youngest shoots which just appeared above ground were put down as having arisen on that date. From the beginning of September fresh tillers which came up from these thousand plants were removed as they were not likely to grow up into mature canes by the usual harvest time (February-March) of this variety.

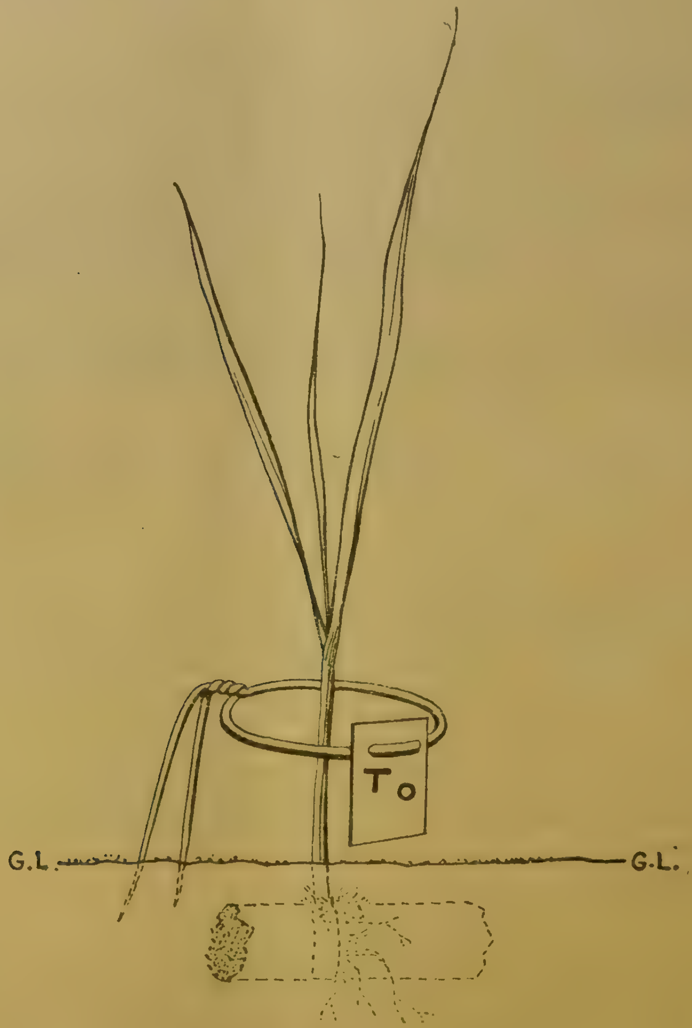

Fig. 1. Labelling of plants

Mortality of shoots due to the incidence of shoot borers was noted in this experiment. Chemical analysis of juices of shoots which arose till about the end of May was also done during the three years this experiment was conducted.

Results and discussion

Tillering and its periodicity. Marking of the 'mother shoots' was completed by 31 March in the first year, 28 March in the second year and 26 March in the third year of this experiment. From certain pot culture experiments Ramiah and Varahalu [1938] deduced that 'there exists a minimum limit for the vegetative growth of any cane variety before the attainment of which no tillers would begin to form'. From this experiment it was found that a minimum growth period of four days was required for a mother shoot to put forth a tiller in 1940-1941, five days in 1941-1942 and twelve days in 1942-1943. The following are the details :—

Table I

Details of tillering

1940-1941		1941-1942		1942-1943	
Date of marking of mother shoot	Earliest date of origin of a tiller	Date of marking of mother shoot	Earliest date of origin of a tiller	Date of marking of mother shoot	Earliest date of origin of a tiller
19th March	31st March	24th March	1st April	24th March	3rd April
23rd March	31st March	26th March	1st April	26th March	1st April
27th March	31st March	28th March	9th April	22nd March	3rd April
31st March	8th April				

'Tillering is the multiplication of shoots in the young plants from the lower short jointed portion of the stem immediately below the ground' [Barber, 1919]. According to Stubbs [1900] suckering depends largely upon room and there is no practical end to the process of suckering provided ample room is given. Light is perhaps, as Barber says, the most important factor affecting tillering. According to Locsin [1936] also sun exposure is a limiting factor for cane growth. It determines the maximum density of population in a field of cane. Hence before there is overcrowding of tillers and lack of room for further development, i.e., in the initial stages of the crop itself, it is reasonable to expect maximum tillering activity. The results of this experiment bear this out.

During all the three years, active tillering phase commenced during the third week of April and extended till the end of May (Fig. 2), except during 1941-1942, when there was a slight revival of the tillering activity towards the end of July. Less than one per cent of the total number of shoots arose on each day of marking earlier or later than this period. Hence maximum number of tillers in Co421 will be formed from the third week of April till the end of May in this locality. In a manurial experiment at Padegaon [1935-1936] in which single budded sets were planted by about the middle of January, maximum number of tillers were formed in April and May alone as at Anakapalle.

Factors that influence the survival and mortality of shoots. Stubbs [1900] at Louisiana observed that over one half of suckers formed died. According to Arceneau [1935] 'Invariably, however, more tillers are produced than can be successfully brought to maturity'. Locsin reports from Philippines that the suckers reach a maximum number, 4 shoots per foot of row, when the cane is 4 to 5 months old, declining afterwards to about 2·4 stalks per foot row.

On an examination of the data in this experiment (Table II) it will be seen that the average number of shoots produced for every plant studied was 6·742 in the first year, 8·491 in the second and 6·133 during the third year. Out of these only 3·411, 2·065 and 1·937 shoots per plant survived during the three years respectively.

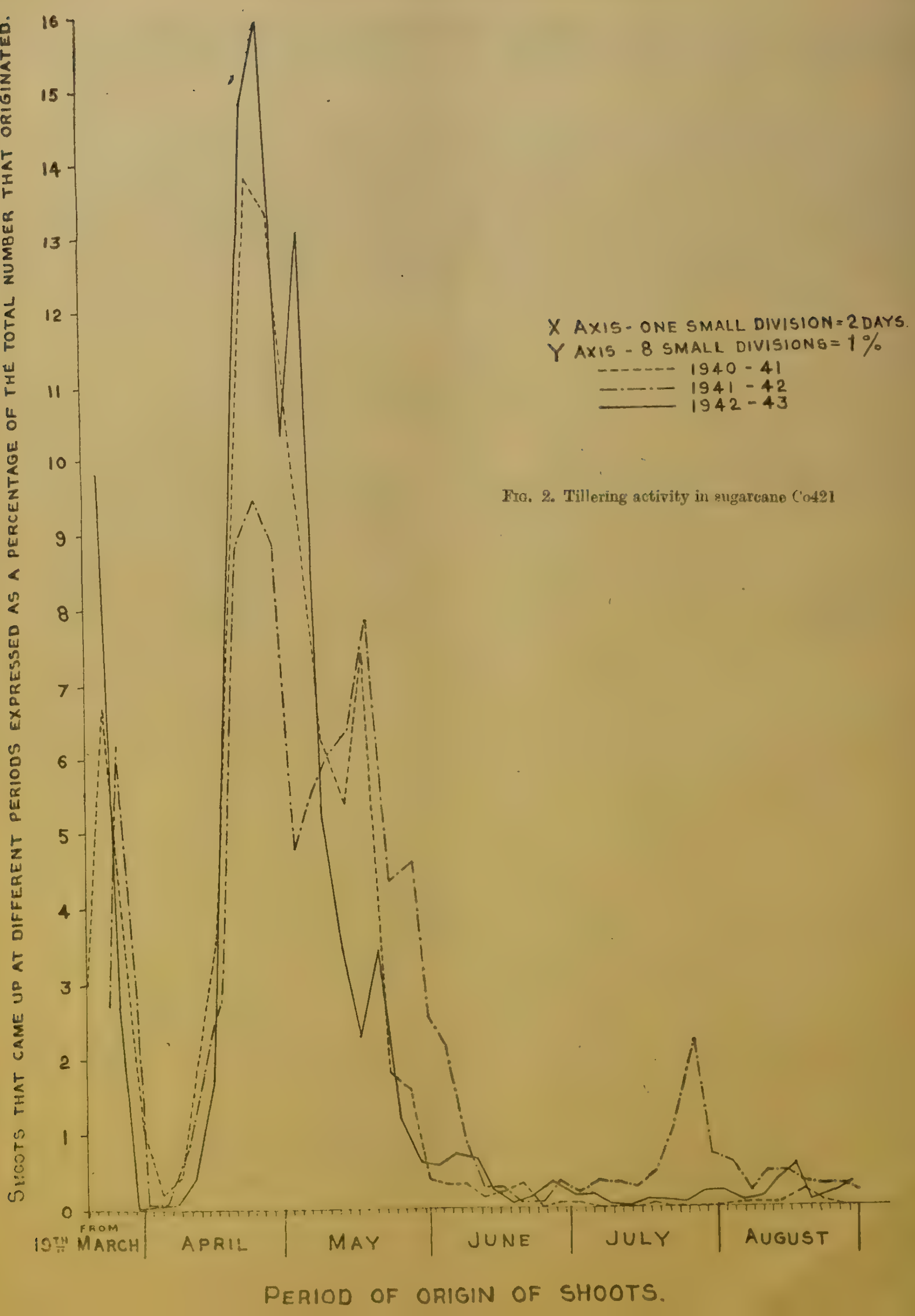

FIG. 2. Tillering activity in sugarcane Co421

TABLE II

Details Regarding the Origin and Survival of Shoots Arising on Different dates of Marking

1940-1941 (Planted 5 March 1940)					1941-1942 (Planted 10 March 1941)					1942-1943 (Planted 8 March 1942)				
Date of marking or origin of shoots	Number of shoots originated	Shoots arising on dif. dates as percentage of total No. originated	Number of shoots that survived	Surviving shoots as percentage of total living population	Date of marking or origin of shoots	Number of shoots originated	Shoots arising on dif. dates as percentage of total No. originated	Number of shoots that survived	Surviving shoots as percentage of total living population	Date of marking or origin of shoots	Number of shoots originated	Shoots arising on dif. dates as percentage of total No. originated	Number of shoots that survived	Surviving shoots as percentage of total living population
19th March	204	3·026	148	4·301	24th March	230	2·716	127	4·945	22nd March	573	9·783	276	14·919
23rd ,,	451	6·689	330	9·590	26th ,,	524	6·187	288	11·215	24th ,,	224	3·824	105	5·676
27th ,,	280	4·153	209	6·074	28th ,,	242	2·857	126	4·901	26th ,,	158	2·698	70	3·784
31st ,,	72	1·068	40	1·162	1st April	6	0·071	..	..	30th ,,	..	..	..	..
4th April	15	0·222	8	0·232	5th ,,	7	0·083	1	0·039	3rd April	2	0·034	1	0·054
8th ,,	30	0·445	23	0·668	9th ,,	70	0·827	30	1·168	7th ,,	5	0·085	3	0·162
12th ,,	142	2·106	108	3·139	13th ,,	149	1·759	65	2·531	11th ,,	24	0·410	13	0·703
16th ,,	241	3·575	191	5·510	17th ,,	227	2·680	116	4·517	15th ,,	100	1·707	50	2·703
20th ,,	540	8·009	386	11·218	21st ,,	750	8·844	356	13·863	19th ,,	352	6·010	177	9·568
24th ,,	927	13·745	657	19·093	25th ,,	799	9·434	351	13·668	23rd ,,	868	14·820	399	21·568
28th ,,	900	13·349	521	15·141	29th ,,	744	8·785	276	10·748	27th ,,	931	15·895	369	19·946
2nd May	731	10·842	337	9·794	3rd May	404	4·770	119	4·634	1st May	602	10·278	158	8·541
6th ,,	546	8·098	183	5·318	7th ,,	469	5·538	126	4·901	5th ,,	765	13·061	130	7·027
10th ,,	425	6·304	126	3·662	11th ,,	616	7·274	124	4·829	9th ,,	301	5·139	28	1·514
14th ,,	363	5·384	69	2·005	15th ,,	547	6·459	126	4·901	13th ,,	202	3·449	24	1·297
18th ,,	501	7·431	60	1·744	19th ,,	664	7·840	114	4·439	17th ,,	132	2·254	9	0·486
23rd ,,	120	1·780	13	0·378	23rd ,,	370	4·369	42	1·636	21st ,,	204	3·483	9	0·486
27th ,,	106	1·572	18	0·523	28th ,,	388	4·581	45	1·752	25th ,,	71	1·212	3	0·162
31st ,,	27	0·400	2	0·058	31st ,,	214	2·527	27	1·051	29th ,,	37	0·632	2	0·108
4th June	23	0·341	3	0·087	4th June	176	2·078	17	0·662	2nd June	34	0·581	2	0·108
8th ,,	21	0·311	..	..	8th ,,	65	0·768	6	0·234	6th ,,	43	0·734	..	..
12th ,,	10	0·148	1	0·029	12th ,,	22	0·260	4	0·156	10th ,,	37	0·632	..	..
16th ,,	13	0·193	..	..	16th ,,	20	0·236	3	0·117	15th ,,	12	0·205	1	0·054
20th ,,	19	0·282	2	0·058	20th ,,	7	0·083	..	..	18th ,,	2	0·034	1	0·054
24th ,,	..	..	..	..	24th ,,	6	0·071	2	0·078	22nd ,,	8	0·137	..	..
28th ,,	5	0·074	..	..	28th ,,	28	0·331	4	0·156	26th ,,	21	0·359	1	0·054
2nd July	4	0·059	..	..	2nd July	18	0·213	1	0·039	1st July	9	0·154	1	0·054
6th ,,	..	..	..	..	6th ,,	31	0·366	1	0·039	4th ,,	11	0·188	..	..
10th ,,	..	..	..	..	10th ,,	30	0·354	3	0·117	8th ,,	5	0·085	..	..
14th ,,	..	..	..	..	14th ,,	26	0·307	6	0·234	12th ,,	1	0·017	..	..
18th ,,	2	0·030	..	..	18th ,,	39	0·461	5	0·195	16th ,,	4	0·068	..	..
22nd ,,	..	..	..	..	22nd ,,	88	1·039	6	0·234	20th ,,	5	0·085	2	0·108
26th ,,	..	..	..	..	26th ,,	189	2·232	10	0·389	24th ,,	2	0·034	..	..
30th ,,	..	..	..	..	30th ,,	61	0·720	8	0·312	28th ,,	9	0·154	1	0·054
3rd August	1	0·015	1	0·029	3rd August	52	0·614	7	0·273	1st August	9	0·154	2	0·108
7th ,,	1	0·015	..	..	8th ,,	17	0·201	4	0·156	5th ,,	1	0·017	1	0·054
11th ,,	3	0·044	1	0·029	11th ,,	40	0·472	4	0·156	9th ,,	4	0·068	1	0·054
15th ,,	..	..	..	..	15th ,,	40	0·472	1	0·039	13th ,,	21	0·359	2	0·108
20th ,,	15	0·222	3	0·087	19th ,,	30	0·354	6	0·234	17th ,,	35	0·598	6	0·324
24th ,,	4	0·059	1	0·029	23rd ,,	23	0·272	4	0·156	21st ,,	5	0·085	..	..
28th ,,	..	..	..	..	27th ,,	23	0·272	1	0·039	25th ,,	11	0·188	2	0·108
					31st ,,	19	0·224	4	0·156	29th ,,	17	0·290	1	0·054
Total	6742		3441			8469		2566			5857		1850	

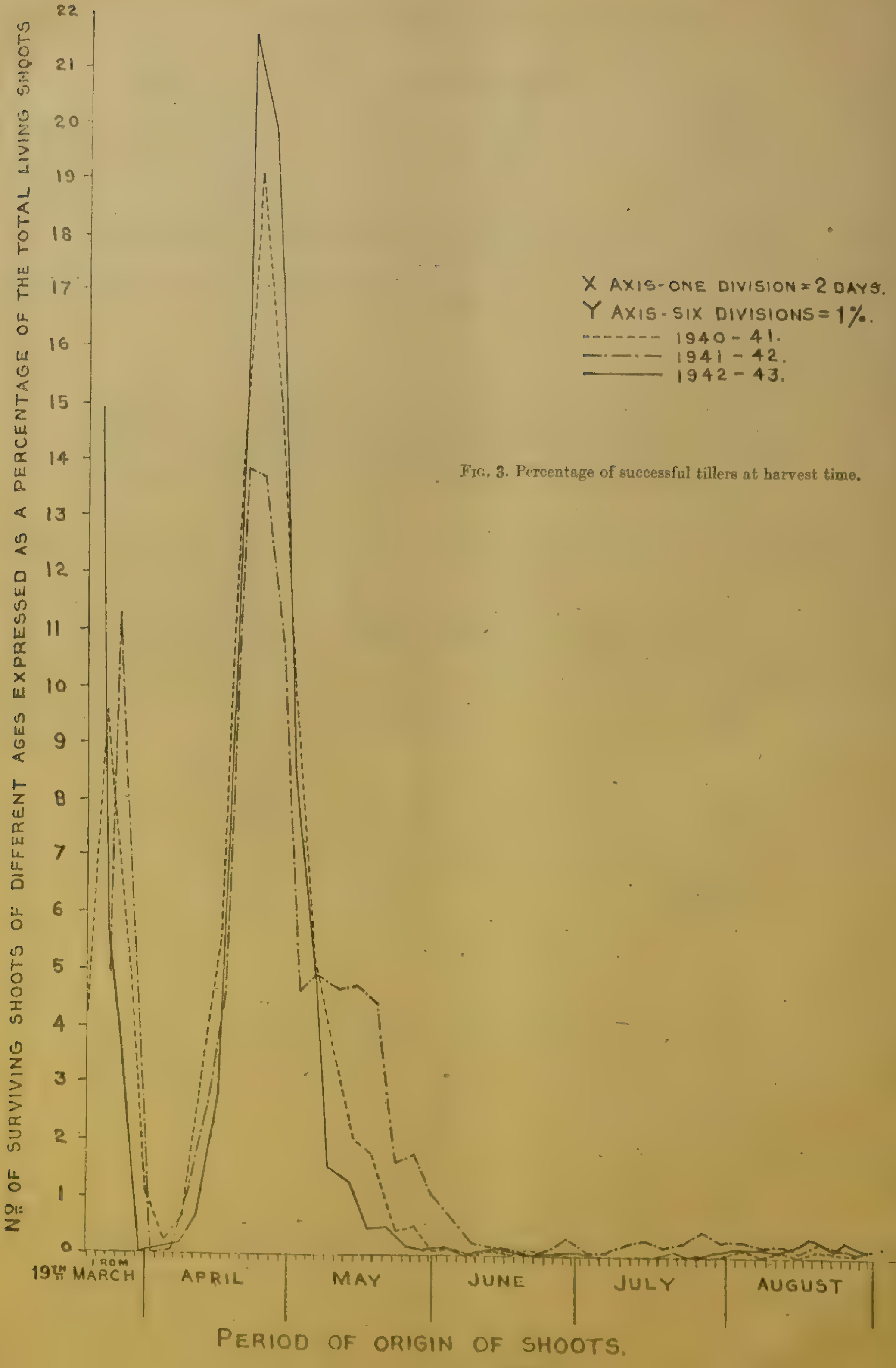

FIG. 3. Percentage of successful tillers at harvest time.

This progressive decline in the number of surviving shoots was due to the unfavourable climatic conditions during the second and third years (vide Appendix—meteorological data, Anakapalle). Distribution of rainfall was even only in the first year. Relative humidity decreased, in general, progressively from year to year and mean maximum temperatures in the early stages of crop growth increased gradually year after year. Among the surviving shoots at harvest time those that originated in April and May formed 78·52 per cent, 74·75 per cent and 74·32 per cent during the three years respectively. Thus the greatest number of successful tillers in the crop originated in the months of April and May alone (Fig. 3). In the experiment at Padegaon [1935-1936] cited before similar results were obtained.

As regards the relationship between age of shoots and their survival, it is seen from Table III that from March to June there was a progressive decrease and then a tendency towards increase in the percentage of surviving shoots to those originated in the same month.

TABLE III

Number of shoots originated and the percentage of surviving shoots to those which arose in the same month

Month	1940-1941			1941-1942			1942-1943		
	Total shoots originated	Surviving shoots	Percentage	Total shoots originated	Surviving shoots	Percentage	Total shoots originated	Surviving shoots	Percentage
March	1007	727	72·19	995	541	54·32	955	451	47·23
April	2795	1894	67·76	2752	1195	43·44	2282	1012	44·34
May	2819	808	28·66	3572	723	20·24	2314	363	15·69
June	91	6	6·59	324	36	11·11	157	5	3·18
July	6	..	..	482	40	8·20	46	4	8·70
August	24	6	25·00	244	31	12·70	103	15	14·56

Total for the three years

Month	Total shoots originated	Surviving shoots	Average percentage
March	2957	1719	58·11
April	7829	4091	52·26
May	8705	1894	21·76
June	572	47	8·22
July	534	44	8·24
August	371	52	14·02

Hence it is not so much the age but other factors, presumably space available, that determine the survival percentage of shoots. Another important point is that successful tillers that arose from June to August constituted a negligible percentage of the surviving population. They formed 0·35 per cent, 4·17 per cent and 1·30 per cent respectively in the three years.

As mentioned already, mortality of shoots due to attack of shoot borers as opposed to other causes was noted in this experiment. Borer damage of stalks which survived even though a number of joints were attacked was not taken into account. The results are presented below (Table IV).

TABLE IV

Borer damage of shoots

		1940-1941			1941-1942			1942-1943		
		Number of shoots	Mortality in shoots due to borer	Percentage	No. of shoots	Mortality in shoots due to borer	Percentage	No. of shoots	Mortality in shoots due to borer	Percentage
Mother shoots		1000	235	23·5	995	415	41·71	955	488	51·10
Tillers which originated	March	7	..	..	..	..	..	..	..	..
	April	2795	749	26·80	2752	1270	46·15	2282	1203	52·72
	May	2819	1444	51·22	3572	1782	49·89	2314	1727	74·63
	June	91	52	57·14	324	124	38·27	157	99	63·06
	July	6	4	66·67	482	192	39·83	46	20	43·48
	August	24	12	50·00	244	51	20·90	103	25	24·27

If we omit out of consideration the insignificant number of shoots that came up from June to August, mortality of 'mother' shoots due to incidence of borers is seen to be less than that in tillers. According to Arceneaux [1935] at Louisiana there was a gradual rise in the percentage of bored joints with a delay in the date of germination within the three sucker groups but the percentage of deaths among mother shoots was much higher than among suckers. This he considers is 'unquestionably due to the fact that borer death counts covered only the early growth period when borer damage was naturally concentrated on mother shoots and older suckers.' The crop which Arceneaux dealt with was planted on 7 October 1933. Mother shoots were marked on 11 April 1934. Group A suckers were marked on 20 April, group B suckers being selected on 29 May. The rest of the suckers were left untagged and constituted group C suckers. And these are the results of only one year's experimentation. Unlike in this case, tillers which arose at particular intervals (4 days) were regularly marked in this experiment (at Anakapalle) for a definite period during all the three years. Mortality of shoots due to borer damage was noted in all the different age groups, but no account was taken of the damage done to individual joints in each stalk. To save space the whole data are not presented here. However, the range of the percentages of deaths due to borer attack in the mother shoots and tillers originating in the different months is furnished below (Table V).

TABLE V

Percentage of deaths due to borer attack

		Range of percentages of deaths due to borer attack		
		1940-1941	1941-1942	1942-1943
Mother shoots		21·07 to 27·78	40·46 to 43·39	50·44 to 53·80
Tillers which arose	April	16·67 to 34·56	38·77 to 83·33	40·00 to 57·68
	May	33·33 to 61·16	38·32 to 56·22	54·05 to 79·07
	June	40·00 to 76·92	33·33 to 60·71	50·00 to 87·50
	July	100 per cent	25·40 to 67·74	22·22 to 100·00
	August	26·67 to 100·00	6·67 to 35·29	14·29 to 75·00

These results are at variance with those obtained by Arceneaux.

Arrowing. Several factors influence arrowing. The inherent tendency of a variety, the seasonal phenomena, effect of environment, and influence of parents are some of the factors. Among the environmental factors which influence the time of arrowing, one of the most important is said to be the photo period or the amount of sunlight received during the different growth periods of sugarcane.*

It is evident from this experiment, that the age of shoot also plays an important part with regard to arrowing. Co421 arrows here usually by about the middle or the third week of November. Among the selected plants, shoots (mother shoots or tillers) that arose up to 18 May in 1940-1941, 3 May in 1941-1942 and 13 May in 1942-1943 only put forth arrows. A minimum growth period of about six months is obviously necessary before a stalk of Co421 can arrow.

Table VI

Correlation between time of origin of shoot and arrowing

1940-1941				1941-1942				1942-1943			
Date of marking	Number of living tillers	Number arrowed	Number of canes arrowed as a per centage of living tillers of the same age	Date of marking	Number of living tillers	Number arrowed	Number of canes arrowed as a per-centage of living tillers of the same age	Date of marking	Number of living tillers	Number arrowed	Number of canes arrowed as a per-centage of living tillers of the same age
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
19th March .	148	48	32·43	24th March .	127	1	0·79	22nd March .	276	96	34·06
23rd „ .	330	93	28·18	26th „ .	285	2	0·70	24th „ .	105	23	21·91
27th „ .	209	39	18·66	28th „ .	126	2	1·58	26th „ .	70	22	31·43
31st „ .	40	4	10·00	1st April .	..	..	..	30th „ .	..	..	..
4th April .	8	2	25·00	5th „ .	1	..	..	3rd April .	1	..	..
8th „ .	23	5	21·74	9th „ .	30	..	..	7th „ .	3	1	33·34
12th „ .	108	24	22·22	13th „ .	65	..	..	11th „ .	13	3	23·08
16th „ .	191	41	21·47	17th „ .	116	1	0·86	15th „ .	50	8	16·00
20th „ .	386	80	20·73	21st „ .	356	2	0·56	19th „ .	177	29	16·39
24th „ .	657	87	13·24	25th „ .	351	2	0·57	23rd „ .	399	66	16·54
28th „ .	521	45	8·64	29th „ .	276	..	..	27th „ .	369	36	9·76
2nd May .	337	12	3·56	3rd May .	119	1	0·84	1st May .	158	10	6·33
6th „ .	183	6	3·28					5th „ .	130	9	7·14
10th „ .	126	1	0·79					9th „ .	28	2	7·14
14th „ .	69	..	..					13th „ .	24	1	4·16
18th „ .	60	1	1·67								

*Annual Report of the Imperial Sugarcane Expert (period ending 30-6-1938).

The percentage of arrowed stalks to total living shoots at harvest time was 14·19 during the first year and 16·55 during the last year. In the second year there was very little arrowing (0·43 per cent). Significant positive correlation, (value of r being +0·8687 and +0·5482 at P =0·05 in the first and third years respectively) was observed between age of shoot and arrowing in the first and third years. [For working out the correlation, the age of shoot is determined as follows: A definite date, end of November, by which time arrowing will be almost complete in this variety, is fixed. The interval (in days) between time of origin 19 March, 23 March etc., and 30 November is taken as the age of the shoots which arose on the different dates. The percentage of arrowing in each age group (Table VI) is known. Correlation coefficient is worked out from this data].

Juice quality. Age is an important factor that influences the sugar content of cane juice. Very young canes will be immature and have poor juice quality. Aged canes will be over ripe and may have poor quality juices. 'In subtropical regions like Louisiana where even the oldest shoots do not as a rule reach physiological maturity, the age differences involved are generally regarded as major sources of variation in the sugar content of the juice' [Arcencaux 1935].

Juices of the mother shoots and tillers which arose on different dates till 18 May in 1940-1941, 28 May in 1941-1942, and 21 May in 1942-1943 were analysed periodically for sucrose and purity values in this experiment. The number of analyses depended upon material available in the various shoots. Results are furnished below (Table VII).

TABLE VII

Results of periodical analyses of juices of shoots arising on different dates

Serial No.		Date of origin of shoot	December		January		March		April		May	
			Sucrose per cent	Purity per cent	Sucrose per cent	Purity per cent	Sucrose per cent	Purity per cent	Sucrose per cent	Purity per cent	Sucrose per cent	Purity per cent
							1940-1941					
1	Mother shoots.	19th March 1940	14·87	85·19	16·50	88·76	17·23	88·76	16·07	88·57	16·18	88·69
2		23rd ,, ,,	14·17	82·68	16·96	89·78	17·23	88·76	16·85	88·04	16·95	89·07
3		27th ,, ,,	14·88	85·84	16·51	89·78	18·45	89·95	18·06	89·23	17·37	89·78
4		31st ,, ,,	14·41	84·59	16·77	88·28	18·42	89·37	18·91	90·33	16·98	89·19
5	Tillers.	16th April ,,	14·13	83·95	16·27	87·98	17·88	88·92	18·10	89·43	17·03	89·41
6		20th ,, ,,	14·46	83·08	16·96	89·29	17·89	87·18	17·70	88·40	17·44	91·09
7		24th ,, ,,	14·21	82·94	15·96	86·68	17·11	87·80	18·36	89·51	17·26	89·95
8		28th ,, ,,	14·19	83·40	16·22	88·16	17·86	88·27	17·86	88·88	17·04	89·55
9		2nd May ,,	14·11	83·84	16·30	87·62	17·40	87·72	17·96	88·75	17·67	90·25
10		6th ,, ,,	13·67	81·15	16·25	87·37	18·08	89·02	18·20	89·50	18·15	91·47
11		10th ,, ,,	13·88	82·00	16·12	87·35						
12		14th ,, ,,	13·40	83·02	15·64	85·15						
13		18th ,, ,,	13·33	80·63	14·83	84·96						

TABLE VII—*contd.*

Results of periodical analyses of juices of shoots arising on different dates

Serial No.		Date of origin of shoot	November Sucrose per cent	November Purity per cent	December Sucrose per cent	December Purity per cent	January Sucrose per cent	January Purity per cent	February Sucrose per cent	February Purity per cent	March Sucrose per cent	March Purity per cent	April Sucrose per cent	April Purity per cent	May Sucrose per cent	May Purity per cent
		1941-1942														
1	Mother shoots.	24th March 1941	12·53	79·80	14·65	85·09	16·93	88·43	16·53	86·34	17·08	89·37	17·76	89·43	17·30	89·82
2		26th ,, ,,	12·53	79·29	14·63	84·48	16·12	87·82	17·40	89·91	18·25	90·76	17·40	87·60	17·99	91·05
3		28th ,, ,,	12·73	78·09	16·08	88·22	17·11	87·96	17·51	89·56	17·63	88·98	17·54	87·44	17·40	87·60
4	Tillers.	17th April ,,	12·54	78·12	14·81	83·83	17·04	87·83	17·49	89·00	18·58	91·19	17·21	87·73	17·20	88·21
5		21st ,, ,,	13·02	80·52	14·41	83·21	16·66	88·42	17·37	89·82	17·86	90·37	17·78	88·62	17·98	90·24
6		25th ,, ,,	12·83	79·56	14·73	83·95	16·75	87·80	17·31	88·97	17·98	90·87	17·07	87·88	17·56	88·99
7		29th ,, ,,	12·22	78·84	14·42	83·67	16·75	87·96	17·22	88·91	18·12	90·79	17·96	88·58	17·16	88·58
8		3rd May ,,	13·27	81·39	14·42	82·87	16·52	87·70	17·40	90·99	18·44	90·44	17·07	87·35	17·81	89·43
9		7th ,, ,,	12·63	77·49	13·42	82·96	16·28	88·50	17·18	90·08	17·94	89·97	17·36	87·05	17·73	88·82
10		11th ,, ,,			14·25	82·73	16·77	87·66	17·65	90·14	17·69	91·10	17·64	88·72	15·54	83·28
11		15th ,, ,,			13·86	82·67	17·13	87·94	16·91	88·88	17·93	90·27	17·05	87·06	17·65	89·32
12		19th ,, ,,			13·61	81·23	17·05	88·18	17·44	89·98	17·60	89·89	17·59	88·00	15·81	86·60
13		23rd ,, ,,			12·73	78·13	16·82	87·79	17·39	89·36	..	..				
14		28th ,, ,,			13·68	81·24	16·46	86·84	16·96	89·00	17·64	90·20				
		1942-1943														
1	Mother shoots.	22nd March 1942	12·26	77·78	14·79	82·62	16·09	85·07	16·45	87·20	17·34	89·89	16·01	86·78	14·89	84·92
2		24th ,, ,,	11·93	76·17	15·78	86·22	17·07	89·13	17·10	88·33	17·54	88·61	17·30	89·13	16·34	88·33
3		26th ,, ,,	12·80	78·23	15·78	86·22	16·11	88·26	18·03	91·09	17·83	90·07	16·77	88·20	17·06	89·13
4		19th April ,,	13·05	79·00	15·22	84·29	16·83	89·49	18·06	90·49	17·36	89·03	17·47	89·30	16·37	89·03
5	Tillers.	23rd ,, ,,	13·03	79·92	15·18	84·85	16·31	88·12	17·50	89·34	18·19	89·80	16·89	88·73	16·32	88·76
6		27th ,, ,,	12·42	78·27	14·99	84·34	16·82	90·00	17·30	88·75	18·01	89·25	17·38	89·17	16·83	89·60
7		1st May ,,	11·84	76·72	14·02	82·43	15·51	87·53	17·56	89·25	17·80	88·44	16·33	87·65	16·68	89·16
8		5th ,, ,,	12·42	78·74	13·83	81·95	16·50	88·35	16·72	87·67	18·82	88·02	16·56	88·24	16·94	90·56
9		9th ,, ,,							16·84	88·25	17·17	87·06				
10		13th ,, ,,							16·89	86·97						
11		17th ,, ,,							15·90	85·67						
12		21st ,, ,,							17·55	90·29						

These figures do not suggest any particular trend in the quality of juices. Even Arceneaux [1935] observed very slight differences in indicated yield of sugar per ton of cane between mother stalks marked on 11 April and suckers of the two older groups marked on 20 April and 29 May respectively. Locsin [1936] reported that stalks of various orders, up to the 5th, came to maturity at about the same time although their start in light is several months apart. In this experiment the maximum age difference between the shoots, whose juice was analysed, was only about two months. This confirms the findings of Varahalu [1936] who said 'it is not only the age but more potent than this in controlling the performance and the maturity of a cane are the seasons of the year through which the crop passes during its stand, the order in which it faces several seasons and the duration of its stay in each one of them'. Shoots which arose by about the end of March as also those which originated by about the end of May together passed through the 'boom' stage (June to October) when there is maximum vegetative development as well as the succeeding winter months, when growth is arrested, and the concentration of cane juices increases. Hence perhaps, there was no marked difference in the quality of juices from the different shoots which were analysed in this experiment.

Summary

Several factors affect yield of sugarcane. Age of crop is one such. Its relationship with tillering, arrowing and the juice quality of different shoots, under normal conditions of manuring and irrigation was studied at Anakapalle during three consecutive seasons, 1940-1941, 1941-1942 and 1942-1943. The variety under trial was Co421.

The following conclusions are drawn :

(1) When plantings are done by about the 10th of March, active tillering phase begins by about the third week of April and extends till the end of May.

(2) The minimum period of growth for a shoot to produce a tiller is four days.

(3) Greatest number of successful tillers originate before the end of May. Hence manuring and other operations designed to improve tillering in this variety will have to be finished earlier than this month. Very few tillers usually arise from June onwards and they can be removed.

(4) Mortality of mother shoots due to borer attack is less than in tillers.

(5) Age of shoot and arrowing are positively correlated.

(6) There is no appreciable difference in the juice quality of shoots which come up till about the end of May. The maturity of all the stalks at harvest time will more or less be uniform if all of them originated before the end of May.

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APPENDIX I

Meteorological data—Anakapalle

Month	1940 Total rain fall	1940 No. of rainy days.	1940 Mean Max. temp.	1940 Mean Min. temp.	1940 Relative humidity	1941 Total rain fall	1941 No. of rainy days	1941 Mean Max. temp.	1941 Mean Min. temp.	1941 Relative humidity	1942 Total rain fall	1942 No. of rainy days	1942 Mean Max. temp.	1942 Mean Min. temp.	1942 Relative humidity
January	..	..	..	..	..	..	..	87·0	64·5	78·9	..	..	85·34	63·45	73·94
February	..	..	..	..	..	2·17	2	88·4	66·8	77·4	..	..	89·17	66·33	77·86
March	4·55	9	89·23	72·52	81·53	0·73	2	94·35	72·11	79·9	..	..	93·96	71·55	78·61
April	0·31	1	96·79	75·59	72·42	0·02	1	97·92	78·72	70·2	0·34	1	95·72	77·26	71·62
May	9·79	10	95·63	79·33	76·44	4·38	9	98·15	80·07	71·6	0·44	3	101·06	82·17	64·11
June	5·29	17	92·59	78·72	80·65	3·52	14	94·26	80·05	70·4	3·36	6	97·73	82·42	71·60
July	3·69	16	89·55	77·55	78·61	2·50	15	94·30	78·44	77·65	2·30	13	91·56	78·91	77·66
August	4·11	15	90·20	76·90	82·26	4·05	15	94·47	78·97	78·94	6·07	10	92·96	77·92	76·45
September	6·73	15	92·25	76·49	79·48	5·57	15	92·24	77·11	85·13	4·69	15	91·15	77·29	84·00
October	5·10	7	89·85	74·45	82·47	13·98	10	89·35	74·70	83·77	7·15	12	88·10	73·41	71·70
November	1·08	5	87·77	70·69	74·23	5·63	6	84·42	66·65	72·88	3·35	6	85·00	69·09	73·03
December	0·03	1	85·80	65·30	73·50	..	..	84·78	67·13	77·90	0·38	1	82·16	65·08	78·80
		1943													
January	0·98	3	84·72	64·75	82·61										
February	0·20	2	83·35	63·17	74·40										
March	..	..	93·50	69·10	74·20										
April	3·79	8	97·65	75·58	78·80										

INFLUENCE OF SOIL MOISTURE ON THE YIELD OF PADDY

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(With Plates XVII & XVIII and two text-figures)

RICE is the main staple crop in Bengal. It is grown all over the province under varieties of conditions which vary from water standing several feet deep on the field, in the case of the deep water paddy, to only moist soil in the case of *Aus* paddy which is generally grown in comparatively highlands where flood water does not generally get entrance or rain water cannot accumulate. When grown in low lying areas it is harvested before the entrance of flood water.

Briggs and Shantz [1914] found a high figure for water requirments of rice plants. The work carried out by the Agriculture Department, Bengal [1925-26], shows that the addition of phosphate to the soil reduces the water requirement.

Sherrard [1920] has shown that draining the rice fields at certain stages to be replaced by fresh water is beneficial to the crop. Singh and singh [1935] found that the transpiration ratio for rice plants is 519 which is quite in agreement with the figure obtained by Briggs and Shantz.

Sen [1937] published the results of an investigation on the water relation of rice plants. Three water conditions of the field were employed, viz. the water standing three inches deep, wet soil and cracked condition. Their effects were studied singly and in combination with one another and it was shown that standing water for about three weeks immediately after transplantation both in the cases of *aus* and *amon* paddy followed by de-watering is beneficial to the plant. Flowering is adversely affected by standing water. His investigations suffer from the lack of informations regarding the exact moisture conditions of the soil beyond the three stages mentioned above.

Although a good deal of work on the subject have seen the light, no systematic investigation on the water relation of rice plants in term of soil moisture, calculated purely on scientific basis, has yet been done. The present investigation was undertaken with the object of seeing how different doses of water applied at different intervals of time influence the growth and ultimately the seed formation of paddy or in other words the experiment was designed to find out the minimum moisture content of soil for *aus* paddy and where irrigation is possible what should be the quantity and interval between the successive periods.

The experiment was conducted with *aus* paddy which does not require any standing water in the field or any water logging but prefers moist soil. This is the autumn paddy in Bengal and is generally grown in the highland tracts and its life cycle is completed in 80-90 days. The sowing time is generally the months of March and April when the rainfall is not very frequent. So during the early stages of growth the land usually dries up to such an extent as to cause permanent wilting of the plants, resulting in either total failure of the crop or abnormally low yield.

The experiment was conducted in the pot culture house so as to obtain strictly controlled condition. The soil used in this experiment was the red soil of the Madhupur Jungle tract as represented by the Dacca Farm. (Physico-chemical properties of this soil will be described elsewhere.)

In this experiment the soil was kept under three moisture conditions, viz.

(1) 75 per cent of the maximum saturation capacity.
(2) 50 per cent ,, ,, ,,
(3) 33 per cent ,, ,, ,,

All these soils were allowed to dry for some definite periods after each addition of water. Thus although the pots were initially brought to a definite percentage of saturation they did not remain so throughout the whole period but lost considerable moisture which was recouped after fresh additions of water after definite intervals of time varying from 3 to 21 days. The loss of moisture from the pots were due to two causes (i) evaporation from the soil, and (ii) transpiration through the leaves. The loss due to the former cause will result in unequal distribution of moisture in the soil in the pot

which is not desirable in an experiment like this. Therefore the loss due to evaporation was reduced to a minimum by tightly covering the pots with rubber cloth.

The soil was thoroughly mixed with cowdung at the rate of 200 gm. of cowdung per 13 kilos of soil. The manured soil was then gradually packed in tin pots (10 in. × 10 in. × 10 in.). Before introducing the soil a perforated earthen pot was placed in an inverted position at the bottom of each tin pot. This perforated earthen pot served as an air chamber to facilitate root respiration. A glass tube about ¼ in. in diameter was introduced in the tin pot through an opening in the wall of the pot and finally let into the inverted earthen pot. Thus the interior of the air chamber was in direct communication with the outside air. Calculated quantity of water necessary to bring the soil to the requisite percentage was sprinkled over the soil. After each addition the soil was thoroughly mixed so that water may be uniformly distributed in the soil. The pots were then kept over night to ensure absorption of water by soil. *Aus* paddy seedlings about three weeks old was transplanted one in each pot. The open faces of the pots were tightly covered with rubber cloth which had a perforation at the centre through which the plants were let out. The opening round the plant was plugged with cotton so that there may not be any loss of moisture due to evaporation. In spite of these precautions certain amount of water evaporated off which was indicated by the loss of weight in the control pots which were similarly treated but no plants were put in. The reason for adopting such a drastic measure to check the loss of moisture due to evaporation is that the evaporation will cause unequal distribution of moisture in the soil—the top soil will be more affected than the soil occupying the lower layers. This sort of unequal distribution of moisture is most objectionable in such an experiment.

The selection of seedlings presented some difficulty. It has already been mentioned that only one seedling was put in each pot so that uniformity of seedlings is essential. Utmost care was taken in selecting plants of equal strength and growth. The selection was based on the number of leaves, the thickness of the stem, the height, etc. After transplantation the pots were kept in a shady place for three or four days in order that the plants may easily take roots. Any plant which showed abnormal growth was replaced by a normal one. Generally it was found that there is hardly any necessity of replacement.

The real experiment was started after 10 days from the day of transplantation when the pots were all weighed and brought to the required saturation by the addition of water where necessary. Thus before starting the experiment, the soil in all the pots of the first series had 33 per cent saturation, second 50 per cent and the third 75 per cent.

The pots in each of the three series were divided into seven groups, each group containing 4 pots, and one group from each series was watered after a definite interval of time. The arrangements of the pots in series and groups and the watering periods are shown in Table I.

TABLE I

Arrangement of pots in series and groups and the watering periods

Particulars	33 per cent saturation 1st series	50 per cent saturation 2nd series	75 per cent saturation 3rd series	Period of watering
	No. of pots	No. of pots	No. of pots	
First group	4	4	4	Every 4th day
Second group	4	4	4	„ 7th day
Third group	4	4	4	„ 10th day
Fourth group	4	4	4	„ 13th day
Fifth group	4	4	4	„ 16th day
Sixth group	4	4	4	„ 19th day
Seventh group	4	4	4	„ 22nd day

As regards the 4th series, 4 pots had 20 per cent saturation and 4 pots 25 per cent saturation and another 4 pots had 33 per cent saturation.

All the pots in the 4th series were watered every day to bring them to the initial saturation.

The pots were placed on trollies and exposed to sun and light during the day but were carefully protected from rain. The loss of moisture from the pots was thus wholly due to transpiration and

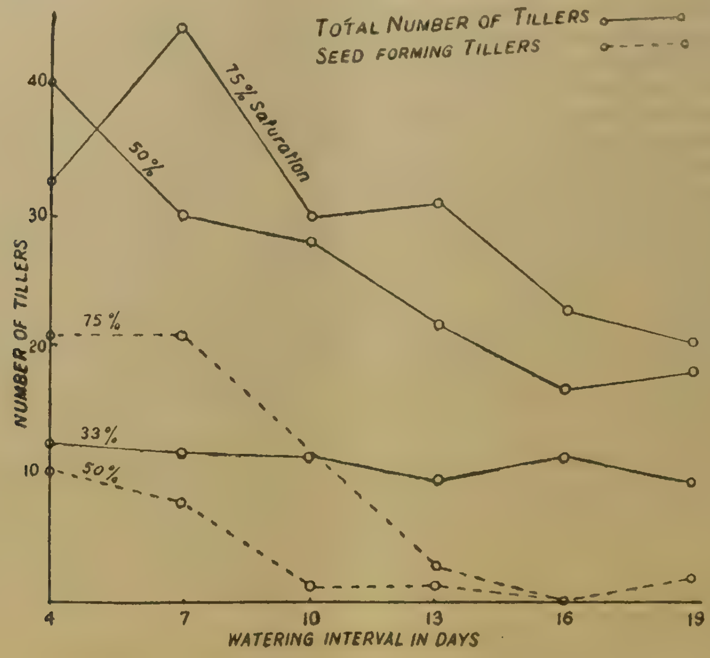


FIG. 1. Saturation and number of tillers

building up of the tissues. The loss due to evaporation from the control pots was negligible in comparison with the loss due to other causes. In no case did the daily loss from the control pots exceed 20 c.c. of water per day. The average daily loss in the control pots was 10 c.c. per day.

All the pots in the 4th series were daily weighed and watered to the initial saturation while the pots of the other series were weighed after the intervals shown in Table I and water added to each pot to bring them to the same water content which they had at the beginning. Thus the pots of the three series were subjected to a drought varying from 2 to 20 days. None of the plants suffered much during the early period of growth when the water requirements were very small but the plants of the 33 per cent saturation series totally lost their potentialities during the latter period even after a lack of water for 2 days as was manifest from their failure to form seed.

The plants of the other series could more or less resist drought up to a maximum of 12 days but the yield was so poor that they may be regarded as total failures.

Fig. 1 shows that none of the pots of 33 per cent saturation formed seeds though some of them flowered, while most of the plants in the other series flowered but those which were subjected to a drought of more than 10 days did not form seed. Groups 1, 2 and 3 of the second and third series formed seed showing that water is essentially necessary during the flowering stage for seed formation.

It will be seen from the Figs. 1 and 2 that in 75 per cent saturation series the number of tillers and the yield of straw jump up in the second group with six days watering interval and then gradually fall down as the interval of watering is increased while in the case of 50 per cent saturation both the number of tillers and the yield of straw fall down systematically with the increase in the watering interval. In 33 per cent saturation the crop is practically a failure one and the watering interval has no appreciable effect either on the tillering or on the yield of straw.

Another interesting feature brought to light in course of this experiment is that there are critical stages in the growth of the plants when absence of sufficient water causes total damage to the crop.

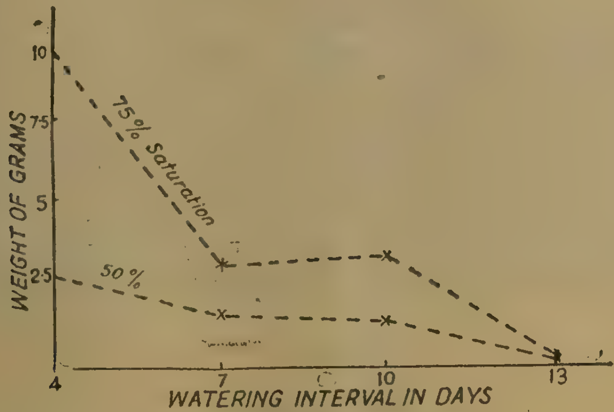


FIG. 2. Saturation and seed formation

Externally the plants wilt and if this wilting continues for some time, some of the more tender parts specially the root hairs are destroyed. The result is that it checks the development of flower buds and the formation of seeds. In the fourth series of pots, which were watered daily, there was a progressive improvement in growth as the saturation increased (Plate XVII). The plants which were kept at 20 per cent saturation, i.e. at 9·2 per cent moisture content, a value slightly above the wilting point of soil though showed healthy growth, did not flower with exception of one.

Plants at 25 per cent saturation formed seed but not as good as the plants in 33 per cent saturation.

The seed formation at 33 per cent saturation, watered daily, was as good as 75 per cent saturation watered every fourth day. The vegetative growth was best in 75 per cent saturation watered every seventh day but was not as good as fourth day group in seed formation (Figs. 1 and 2).

TABLE II

Analysis of variance—straw

Particulars	Degree of freedom	Sum of squares	Mean squares	S.D.
Interval	5	447·17	74·53	
Per cent saturation	2	1951·44	975·72	
Interaction	12	159·96	13·33	
	20	2558·57		
Residual	63	227·90	3·62	1·903
Total	83	2786·47		

S.E.=1·903

TABLE III

Analysis of variance—tillers

Particulars	Degree of freedom	Sum of squares	Mean squares	S.D.
Interval	6	2432	405·3	
Per cent saturation	2	4781	2390·5	
Interaction	12	1450	120·8	
	20	8636		
Residual	63	2027	32·17	5·67
Total	83	10690		

S.E.=5·67

TABLE IV

Height of the plants

Particulars	Degree of freedom	Sum of squares	Mean squares	S.D.
Interval	6	540·96	90·16	
Per cent saturation	2	1365·09	682·54	
Interaction	12	67·62	5·63	
	20	1973·67		
Residual	63	410·20	6·51	2·55
Total	83	2383·87		

S.E.=2·55

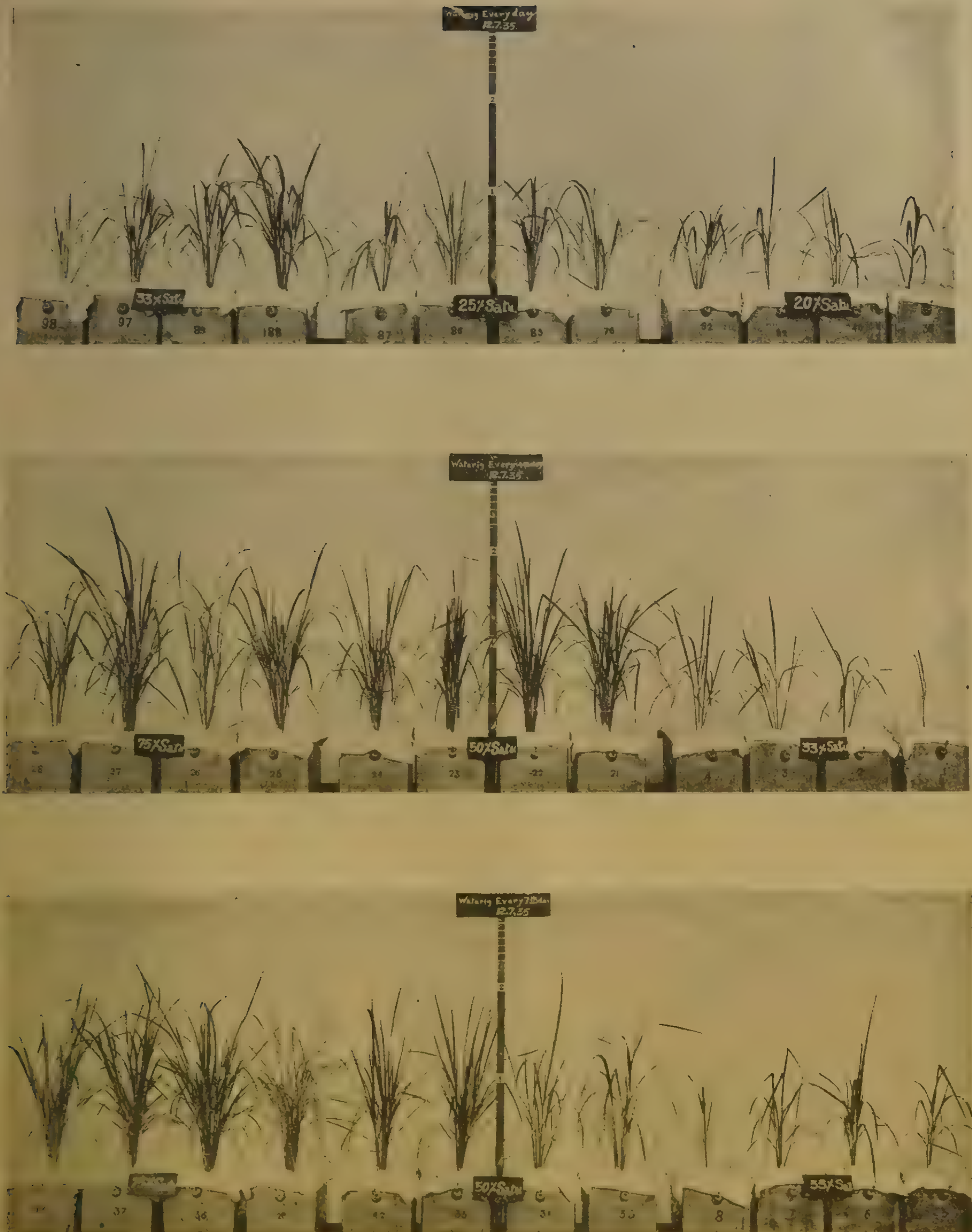
On examining the results in the above analyses it will be found that the effect of percentage difference in saturation is more pronounced in height, tillering and in the yield of straw than the interval though highly significant improvement is noticed as the interval is decreased in the same saturation. The most striking point is that every seventh day watering group of 75 per cent saturation series recorded the highest yield in straw and better than every fourth day watering group of the same series, while the yield of grain has been much better in every fourth day watering group, indicates that with 75 per cent saturation, watering every fourth day during the early stage of growth is detrimental to tillering but essential for seed formation.

A photographic examination of the plants (Plate XVIII) shows that on 12th July 1935 every fourth day watering group of 50 per cent saturation is better than the same group of 75 per cent series. But the final photographs taken immediately before harvest (Plate XVIII) show that all the groups of 75 per cent saturation are decidedly better than the respective groups of the other series.

SUMMARY

The water requirements of rice plants in terms of soil moisture has been investigated. The experiment was conducted in the pot culture house. The soil was initially kept in three moisture conditions called series

(1) 33 per cent of the soil saturation capacity
(2) 50 per cent ,, ,, ,,
(3) 75 per cent ,, ,, ,,



Effect of watering on the growth of paddy. *Top:* Watering every day. *Centre:* Watering every 4th day. *Below:* Watering every 7th day

Effect of watering on the growth of paddy. *Top:* Watering every day. *Centre:* Watering every 3rd day. *Below:* Watering every 6th day

Each series was sub-divided into seven groups and each group was watered after intervals of 3 days, 6 days, 9 days, and so on up to 21 days.

It has been found that during the early stages of growth the plants were not much affected by the interval of watering. But during the latter stages they were so affected as to result in a total failure of the crop. Thus the plants could not stand watering at the interval of 3 days, 6 days, and 9 days in the cases of 33 per cent. 50 per cent and 75 per cent saturations respectively.

In the case of the 75 per cent saturation series, every seventh day watering group recorded higher yield in straw than every fourth day watering group of the same series, while the yield of the grain was better in every fourth day watering group of 75 per cent saturation series. The conclusion is that excessive water at the early stages of growth of paddy is detrimental to tillering but essential for seed formation. Further the effect of percentage difference from series to series is not so pronounced as that of the interval.

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SOILS OF BENGAL AND THEIR PHYSICO-CHEMICAL CLASSIFICATION

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(With four text-figures)

BENGAL is intersected by a net work of rivers and channels which derive their origin from different sources and pass through different tracts before entering Bengal. They naturally carry deposits of quite different character and composition. The soils of the province are, therefore, greatly influenced by these rivers. Apart from the river alluvium a considerable portion of the province is occupied by sedentary soil. A broad classification of the soils on the basis of their physico-chemical characteristics has been attempted here.

The soils of the province can thus be broadly put into two great divisions, the alluvial and the sedentary. The bulk of the soil of the province is alluvial while sedentary soils can be found only in the districts of Bankura, Birbhum, Midnapore, Burdwan, Jalpaiguri and Darjeeling. In these parts of the province the rock materials of which the soil is formed are still undergoing transformation. In some places the top few feet are covered with a culturable soil while below it undecomposed rocky strata can be found.

The alluvial soil of the Province can again be divided into two groups, the red soil and the new alluvial soil. Apart from the physical and chemical characteristics, the red soil is distinguished from the new alluvial soil by the characteristic red colour. The Madhupur Jungle tract of East Bengal and the Barind tract of North Bengal form the bulk of this red soil. The rest of the province

is under the new alluvial soil. The area covered by the new alluvial soil is much greater than the area covered by the other two, the red soils and the sedentary soils. These are the main outlines of the principal soil divisions of the presidency.

The red soil represent a type of sandy loam with increasing percentage of clay in the lower horizon. They are very poor in organic matter and are highly acid in reaction. The chemical composition shows that they are poor in lime and phosphoric acid but moderately rich in potash (Table I).

The sedentary soils of the Burdwan Division which are also deficient in lime and phosphoric acid differ widely in physical characteristics from the red soils of the Madhupur Jungle tract. These soils are full of gravels of various sizes and shapes which are still undergoing further disintegration. The surface soil is full of concretionery materials and in some places the concretions have attained such a development as to preclude the growth of vegetation.

The new alluvial soils represent the largest and the most important soil divisions of the Province. They vary from fairly coarse sand on the *chars* (island in rivers) and on the banks of the rivers to soils of very close texture on the low lying (marshes) tracts. The new alluvial soils are generally very rich in plant food and grow all sorts of crops.

List of soils used

METHODS EMPLOYED

Sample No.	Locality	Description
Ps. 10	Barisal	Grey with white tint. New alluvial soil of recent origin
Ps. 16	Nadia	Grey, New alluvial soil (Gangetic)
Ps. 17	Bankura	Laterite soil, Sedentary. Red with brown tint
Ps. 18	Burdwan	Deep brown with reddish tint, Laterite soil
Ps. 19	Dacca Madhupur Jungle tract	Red with yellow tint, alluvial soil, highland
Ps. 20	Dacca	Grey. New alluvial soil
Ps. 21	Dacca Madhupur Jungle tract	Reddish brown, alluvial soil, lowland
Ps. 22	Rangpur	Grey, with ashy tint, mixed with micaceous flakes, Teesta silt
Ps. 23	Rajshahi	Grey, new alluvial soil, Ganges silt
Ps. 24	Dinajpur	Grey, new alluvial soil
Ps. 25	Chittagong	Grey with white tint, alluvial deposit at the extreme end of the Sitakund Hills
Ps. 26	Midnapore	Brown with yellow tint, laterite soil
Ps. 27	Mritadaspur (Birbhum district)	Brown with yellow tint, laterite soil, Sedentary
Ps. 14	Birbhum	Brown with yellow tint, laterite soil, Sedentary

The soil samples were prepared by passing through 1 mm. sieve with round holes.

Loss on ignition. About 10 gm. of air dry soil was ignited in a platinum basin over a bunsen flame until constant weight was obtained.

Mechanical analysis. Clay and silt was determined by international method.

Moisture holding capacity was determined by Keen and Raczkowski method [1921] as modified by Coutts [1930].

Moisture content at half saturation was determined by Keen and Coutts [1928] methods.

Chemical analysis was done by the Standard A.O.A.C. method.

TABLE I

Chemical analysis of soils—Laterite and red soil group

Name of soils	Insoluble residue percentage	K_2O total percentage	CaO total percentage	MgO total percentage	P_2O_5 total percentage	Nitrogen percentage
Ps. 14	93·86	0·26	0·11	0·12	0·036	0·036
Ps. 17	81·19	0·26	0·37	..	0·028	0·032
Ps. 18	84·34	0·58	0·47	0·67	0·029	0·042
Ps. 19	83·93	0·75	0·16	0·35	0·058	0·084
Ps. 21	84·58	0·71	0·098	0·31	0·047	0·11
Ps. 26	90·15	0·272	0·202	0·152	0·018	0·046
Other group						
Ps. 10	76·95	1·01	2·20	1·97	0·14	0·110
Ps. 16	85·83	0·915	0·579	0·85	0·249	0·063
Ps. 20	79·95	0·98	1·35	1·94	0·128	0·036
Ps. 22	79·50	1·18	0·26	1·77	0·103	0·106
Ps. 23	71·80	1·41	2·97	2·11	0·128	0·105
Ps. 24	81·83	0·779	0·279	1·133	0·083	0·039

TABLE II

Composition of the clay fraction—Laterite and red soil group

—	Silica	Fe_2O_3	Al_2O_3	SiO_2/Al_2O_3	SiO_2/R_2O_3
Dacca (H) (Ps. 19)	39·60	9·00	25·33	2·60	2·162
Suri (Ps. 14)	44·91	11·37	25·35	3·00	2·336
Bankura (Ps. 17)	44·73	12·70	26·35	2·88	2·203
Burdwan (Ps. 18)	45·27	11·76	23·04	3·30	2·515
Dacca (Low) (Ps. 21)	39·30	7·44	27·935	2·40	2·040
Midnapur (Ps. 26)	38·26	11·03	29·12	2·20	1·795
Other group					
Barisal (Ps. 10)	44·60	14·19	22·385	3·37	2·405
Rangpur (Ps. 22)	39·52	12·39	26·735	2·48	1·936
Rajshahi (Ps. 23)	43·08	14·74	22·95	3·57	2·258
Dacca (silt) (Ps. 20)	48·32	11·19	25·06	3·27	2·546
Nadia (Ps. 16)	44·14	12·66	24·09	3·11	2·328
Dinajpur (Ps. 24)	38·44	11·46	27·12	2·40	1·893

The chemical analysis in Table I shows that the soils of the so-called laterite and red soil group are poorer than the soils of the other group in all the constituents particularly in phosphoric acid and potash. The nitrogen figures in general are also lower in the 1st group than that in the other group. Ps. 21 which is a low land soil is however a solitary exception in the 1st group.

It was expected that the composition of the clay fraction would give a valuable information as to the nature of the soils and would thereby furnish a dependable basis of classification. But it is practically of no value in this particular case. The figures for silica/alumina ratio in Table II is rather misleading. The ratios in all cases is above 2·00. Therefore according to the definition of Martin and Doyne [1930] none of the soils fall under the group 'laterite'. At any rate these soils form a group themselves and are quite different from the soils of the other group and are more akin to the laterite soils. In absence of any morphological study no definite conclusion is possible at this stage.

A scrutiny of the figures in Table II, however, shows that the Silica/Allumina ratio of the non-laterite group is slightly higher. But no sharp line of demarkation is possible. The Fe_2O_3 figures in the so-called laterite group is definitely lower than those in the non laterite group. This does not however mean much in the matter of classification.

TABLE III

Mechanical analysis—Laterite and red soil group

Sample No.	Clay	Silt
Ps. 14	9·00	..
Ps. 17	20·35	7·45
Ps. 18	13·13	12·22
Ps. 19	23·90	27·62
Ps. 21	27·05	34·80
Ps. 26	14·45	23·55
Ps. 27	9·90	21·25
Other group		
Ps. 10	18·60	38·00
Ps. 16	15·50	29·10
Ps. 20	21·25	58·05
Ps. 22	11·55	23·50
Ps. 23	18·70	33·62
Ps. 24	16·10	27·95
Ps. 25	12·75	42·75

TABLE IV

Results of physical measurements—Laterite and red soil group

Soil No.	Loss on ignition	Percentage of moisture at 50 per cent humidity	Apparent sp. gr.	Percentage of water holding capacity	Percentage of pore space	Real sp. gr.	Percentage of volume expansion	Percentage of sticky point moisture
Ps. 14	1·54	0·07	1·57	28·30	41·50	2·50	4·90	12·10
Ps. 17	3·56	0·54	1·41	31·45	42·15	2·31	6·13	15·10
Ps. 18	3·39	0·87	1·20	39·50	46·70	2·31	11·40	20·04
Ps. 19	4·29	1·15	1·28	46·60	52·00	2·43	8·56	28·43
Ps. 21	4·42	1·26	1·24	54·20	56·70	2·42	12·97	29·75
Ps. 26	3·16	..	1·47	32·91	42·20	2·28	9·70	16·50
Ps. 27	2·37	..	1·51	28·12	40·20	2·39	6·30	15·60
Other group								
Ps. 10	3·67	1·12	1·14	56·60	56·29	2·35	10·35	29·33
Ps. 16	1·97	0·59	1·32	49·20	56·80	2·20	10·50	25·18
Ps. 20	3·58	1·69	1·09	60·41	57·53	2·23	12·11	37·00
Ps. 22	4·30	0·89	1·16	51·95	54·89	2·36	6·50	29·70
Ps. 23	4·98	1·67	1·07	61·50	59·61	2·42	8·25	25·06
Ps. 24	4·44	..	1·32	46·37	53·88	2·52	8·50	25·25
Ps. 25	3·61	..	1·28	44·12	55·84	2·86	8·26	27·8[illegible]

Soil exhibits certain characteristic physico-chemical behaviour specially when associated with water. A detailed study of the physical properties of the moist soil was, therefore, initiated with a view to elucidate the general character of these soils by a quantitative assessment of one property or a group of properties.

Mechanical analysis, however, furnishes a valuable information regarding the make up of the soil but such data do not provide any basis of specification. The soil character is not influenced so much by the size of the different particles, of which the soil is made up, as by their inherent character. The latter influences the moisture relationship to such an extent that this relation serves as a valuable guide for the proper specification of the soil.

Keen and Coutts [1928] stressed the importance of specifying the soil by a single number and introduced the term ' single value soil constant ' and such methods were given the name ' single value determination '. These authors critically examined some of the values such as the moisture

content at 50 per cent relative humidity (R), loss on ignition (I), and sticky point moisture (S) against the clay fraction (C). The correlations between the different constants were worked out by Fisher's method and they obtained definitely significant cœfficients. Their figures are given below :

—	Original soil			—	Peroxide treated soil		
	I	R	S		I	R	S
C	0·364	0·719	0·317	C	0·662	0·760	0·675
I	..	0·388	0·865	I	..	0·386	0·879
R	..	..	0·503	R	..	..	0·584

The highest figures were obtained in the case of C and R and also in the case of S and I.

They also calculated the partial correlation between C and R where I was eliminated and between S and I where C was eliminated and concluded that the value of the sticky point is largely controlled by the material in the soil that is driven off by ignition while the moisture content at half vapour pressure is controlled more by the clay content. Sen and Deb [1941] from a similar study of the Indian laterite and red soils observed that the moisture content at half saturation and the stickly point are largely controlled by the material in the soil that is driven off by ignition.

The figures in Table IV show that the new alluvial soils of Bengal have higher moisture holding capacity and higher sticky point moisture and retain more moisture at half saturation than the laterite and the red soils having the same clay content. The volume expansion on swelling is also higher in the case of the new alluvial soils than the soils of the other group. Similar observations were made by Hardy [1923] who found comparatively low sticky point for soils having low silica/alumina ratio. The same author [1925] also reported low swelling coefficients for the laterite soils of Barbados and Dominica. Marchand and Van der Merwe [1926] obtained similar results in the case of the Transvaal soils.

For a proper understanding of the character of the soils of Bengal a comparative study of some of the physical constants such as the water holding capacity (m), pore space (p), sticky point moisture (s), volume expansion (v) in Table IV, on the one hand and the clay content (c) on the other has been made.

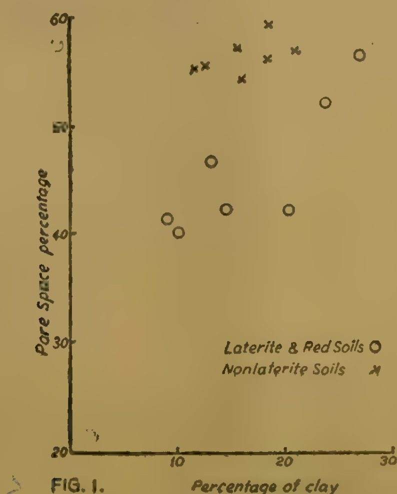

FIG. 1. Scatter diagram of soils

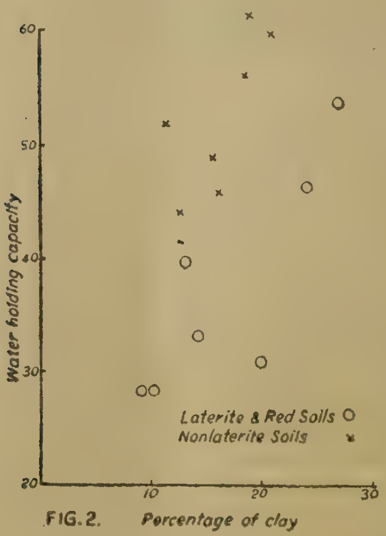

FIG. 2. Scatter diagram of soils

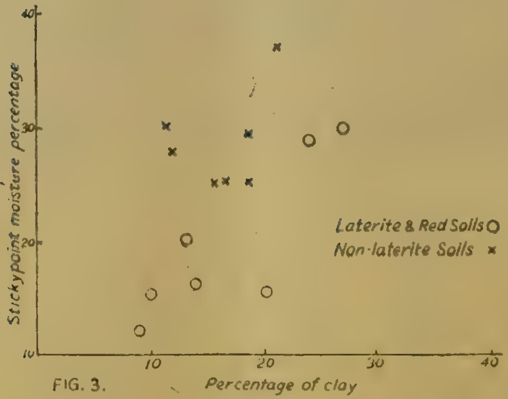

FIG. 3. Scatter diagram of soils

The correlation coefficients are given below :

Cm=0·525,
Cp=0·434,
Cs=0·507,
Cv=0·651.

It is clear from the above figures that the clay content of the Bengal soils bears no relation with any of the constants. Keen and Raczkowski [1921] found that these constants are linearly related with the clay content. Keen and Coutts [1928] report high correlation coefficient for a number of British soils. Marchand [1924] and Coutts [1929] in the case of the Transvaal and Natal soils respectively found high correlation coefficient between the above values. The red soils and the Indian laterite soils also show high correlation coefficient between the above values except in the

case of volume expansion [Sen and Deb 1941]. These authors could not discover any relation between the volume expansion and the clay content.

The absence of any association between any of the above values and the clay content in the case of the Bengal soils led the author to examine the values in more detail. Each of the values were plotted against the clay content for further scrutiny. It may be seen from the scatter diagrams in Figs. 1-4 that the soils examined here fall under two different groups. The laterite and the red soils fall under one group and the rest, i.e. the non-laterite or rather the new alluvial soils, in another. The values in each group are associated with the clay content. It therefore suggests that these soils deserve to be examined separately and cannot be pooled up together. These associations

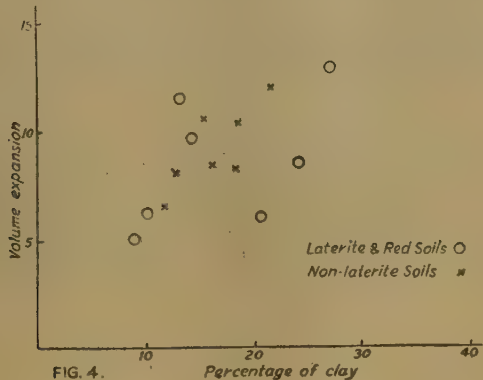

FIG. 4.

Fig. 4. Scatter diagram of soils

between the different values and the clay content when expressed in terms of correlation co-efficient for each group give the following values :

—	Laterite and red soil group	Non-laterite group
rcm	0·950	0·750
rcp	0·874	0·582
rcs	0·868	0·404
rcv	0·648	0·775

It will be seen from the above that the correlation coefficient in the case of the laterite and the red soils are significant at 1 per cent level in all cases except in the case of the volume expansion. In the other group, however, significant values are obtained only in the case of moisture holding capacity and volume expansion and that too just at 5 per cent level of significance.

The regression equations are :

$$\left.\begin{array}{l} c=0{\cdot}649\, m-6{\cdot}78 \\ c=0{\cdot}951\, p-25{\cdot}95 \end{array}\right\} \text{For soils of laterite group.}$$

$$\left.\begin{array}{l} c=0{\cdot}382\, m-3{\cdot}84 \\ c=1{\cdot}081\, p-44{\cdot}64 \end{array}\right\} \text{For non-laterite group.}$$

These values are different from what was obtained by Sen and Deb [1941], *viz.*

$c=0{\cdot}9296\, m-8{\cdot}935.$
$c=1{\cdot}367\, p-32{\cdot}085.$

They also report that in 30-40 per cent cases the relations break down. Similar observations were made by Marchand [1924]. The results obtained here show little difference between the observed and the calculated values.

Summary

A physico-chemical classification of the soils of Bengal based on moisture relationship has been attempted. The classification suggests the possibility of grouping the soils under two heads, the laterite and the red soils falling under one head and the rest under the other. In each group certain properties can be correlated with the clay content of the soil. The results show that the heavy clay soils have the highest ignition losses, maximum water holding capacity and sticky point moisture. No correlation could be found between the volume expansion and the clay content. While in the non-laterite group significant correlation coefficient could be found in the case of the maximum moisture holding capacity and volume expansion.

Acknowledgements

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THE VERTICAL DISTRIBUTION OF PHOSPHATES IN CALCAREOUS SOILS

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(With one text-figure)

The soil is not a homogeneous body of constant composition, being formed from the weathering of various rocks of different geological origin. It consists of several minerals intermixed in different proportions at different layers. Like every other soil constituent, its phosphate status is also likely to be variable. It is well known that plant roots forage in both surface soil and sub-soil, finding the phosphate in the latter as readily available as in the former. The greater portion of that entering the roots is deposited in the aerial parts of the plant, and later, on the decay of leaves and stems, is left on the surface. Each succeeding season will thus witness a new draft upon the phosphate of

the sub-soil without any return. Ramann [1911], however, noticed that the distribution of phosphate in successive horizontal soil layers is not governed by any universal rule. For example, Wohltmann [1901] found that the surface soil of western Germany is sometimes richer and sometimes poorer in phosphate than the corresponding sub-soil, and Kossowitsch [1912] noticed in the Chernozem soils of Russia that the phosphate content is somewhat higher in the first 4 to 8 in. than in the underlying layers. Similarly Hopkins [1910] and Brown [1914] found respectively in the prairie soils of Illinois and Iowa a higher percentage in the surface than in either the sub-surface or the sub-soil. Alway and Isham [1916], however, noticed in the loess soils of Nebraska that the proportion of phosphate is generally smaller in the first and the second foot than in the lower layers. On the other hand, Alway and Rost [1916] found that prairie loess soils of Nebraska in the surface foot show a steady decrease in phosphate from the surface inch downward, independent of the aridity of the climate in which they have formed. Peter [1916] draws attention to the peculiar distribution in the vertical sections of soil from the experiment station at Lexington and points out that it corresponds strikingly with the distribution of phosphate in the phosphatic limestone beds of this vicinity.

The manuring and cropping may also have some effect on the phosphate penetration in field soils. Stephenson and Chapman [1931], comparing soils receiving from 1 to 30 or more annual applications of a phosphate-carrying fertilizer with similar soils which had not received phosphate, showed appreciable penetration of the phosphate below the surface foot in light-textured to medium-textured soils, and little or no penetration in very heavy soils. Similarly Thor [1933] found that on the more compact soil there was definite downward movement of phosphate into 7 to 14 in. depth, but only a slight movement into 14 to 21 in. depth. On the other hand, Crawley [1902], on applying superphosphate, found that nearly the whole of the phosphoric acid remained within 6 in. of the surface and that more than half remained in the first inch of the soil. Van Alstine [1918] and several other workers too found that when phosphate is used as a fertilizer, it remains almost where it is placed in the soil until removed in crops or by some such process as erosion by water or wind action.

Calcareous soils of Pusa in Bihar are particularly deficient in readily available phosphate and respond to phosphate fertilization for proper crop production. It, therefore, became of interest to know the vertical distribution of phosphate in these soils and the effect of cropping and fertilizer practices on it. The work of Warington [1873], Cameron and Bell [1907], Basset [1917], De Jong [1926], Gassman [1928], Kramer and Shear [1928], and McGeorge and Breazeale [1931] shows that phosphorus is present in calcareous soils as calcium carbonato-phosphate or carbonato-apatite, a compound formed of three molecules of tricalcium phosphate and one molecule of calcium carbonate in which the calcium carbonate is an integral part of the complex molecule. The carbonato-phosphate must dissociate to enable the plant to absorb the phosphate ion. The dissociation of this compound is greatly reduced in the presence of the common ion calcium, and is still further reduced by the solid phase calcium carbonate in the presence of the calcium ion. This leads to the comparative unavailability of native calcium phosphate in calcareous soils here.

Experimental

In order to find out the distribution of phosphates in these soils, 3-inch soil borings down to a depth of five feet from some permanent manurial plots of the Chemical Section in Pusa calcareous soils (at the old site of the Imperial Agricultural Research Institute at Pusa) were taken to examine their total phosphate contents. These permanent manurial plots, 20 ft. by 25 ft. each, were laid out in 1920. Manure were applied to the plots once every year just before the monsoon. In these plots *ragi* (*Eleusine coracana*) was raised as *kharif* (summer) crop, followed by either wheat or oats as the *rabi* (winter) crop. Before the date of collecting soil borings in 1933, *ragi* was raised in these plots for 14 seasons, and wheat and oats for 2 and 11 seasons respectively. Phosphate and potash were applied as superphosphate and potassium sulphate respectively for 14 years. The results obtained are given in Table I with the $CaCO_3$ content of the corresponding soil layers. An adjacent fallow plot was also included in this study for comparison.

Table I

Total P_2O_5 and $CaCO_3$ contents of 3-inch soil sections of two permanent manurial plots and a fallow plot in Pusa calcareous soil

3-inch soil sections	Depth in inches	Fallow plot		Plot No. 8 P superphosphate		Plot No. 9 K potassium sulphate	
		Percentage $CaCO_3$	Percentage P_2O_5 in mg.	Percentage $CaCO_3$	Percentage P_2O_5 in mg.	Percentage $CaCO_3$	Percentage P_2O_5 in mg.
1 . . .	0—3	37·60	81·6	36·15	132·3	35·65	91·5
. . .	3—6	37·08	79·4	36·43	101·4	35·93	87·1
3 . . .	6—9	36·93	79·4	36·68	90·4	36·75	82·7
4 . . .	9—12	36·43	81·6	37·15	77·2	36·50	72·8
5 . . .	12—15	36·85	81·6	37·73	81·6	36·00	69·5
6 . . .	15—18	36·88	77·2	39·35	77·2	38·43	72·8
7 . . .	18—21	37·68	70·6	43·50	65·1	40·93	66·2
8 . . .	21—24	37·25	66·2	46·25	58·4	42·98	58·4
9 . . .	24—27	38·09	66·2	46·85	59·5	44·35	56·2
10 . . .	27—30	38·48	64·0	46·60	59·5	46·18	49·6
11 . . .	30—33	38·75	64·0	47·25	55·1	44·75	51·8
12 . . .	33—36	40·00	61·7	44·10	50·7	35·65	81·6
13 . . .	36—39	38·75	65·1	32·25	75·0	30·93	95·9
14 . . .	39—42	39·75	66·2	33·50	72·8	30·50	81·6
15 . . .	42—45	40·25	66·2	33·23	68·4	33·23	88·2
16 . . .	45—48	40·58	64·0	45·18	44·1	45·23	54·0
17 . . .	48—51	41·23	71·7	47·50	54·0	46·75	52·9
18 . .	51—54	41·33	72·8	44·58	48·5	44·25	58·4
19 . . .	54—57	42·50	66·2	45·50	50·7	45·23	56·2
20 . . .	57—60	43·68	60·6	45·23	57·3	44·93	58·4

In order to get an approximate idea of the distribution of phosphate and its relation to the corresponding $CaCO_3$ contents at different depths the per cent average P_2O_5 and $CaCO_3$ per foot are stated in Table II.

Table II

Per cent average P_2O_5 and $CaCO_3$ per foot of the fallow and the two permanent manurial plots in Pusa calcareous soil

Depth	Fallow plot		Plot No. 8 P superphosphate		Plot No. 9 K potassium sulphate	
	Percentage $CaCO_3$	Percentage P_2O_5 in mg.	Percentage $CaCO_3$	Percentage P_2O_5 in mg.	Percentage $CaCO_3$	Percentage P_2O_5 in mg.
1st foot	37·01	80·5	36·60	100·3	36·21	83·5
2nd ,, ...	37·17	73·9	41·71	70·6	39·59	66·7
3rd ,, ...	38·81	64·0	46·20	56·2	42·73	59·8
4th ,, ...	39·83	65·4	36·04	65·1	34·97	79·9
5th ,, ...	42·19	67·8	45·70	52·6	45·29	56·5

From Table II it is seen that in the fallow plot the P_2O_5 content varies almost inversely with the increase of $CaCO_3$ concentration and with depth. In the other two plots a similar relationship holds in the individual depths. In the fourth foot there exists a minimum $CaCO_3$ concentration

preceded and followed by maximum carbonate concentrations in third and fifth foot respectively. The corresponding P_2O_5 contents bear out the same inverse relation with $CaCO_3$ as in the fallow plot. The soil in the first foot of every plot contains the maximum phosphate concentration. The superphosphate plot was manured every year and consequently shows the highest P_2O_5 concentration in the surface foot, but the applied phosphate does not seem to penetrate below one foot. In the potassium sulphate plot the sub-soils contain on the average much less phosphate as would be expected owing to the growing crops making new drafts every year on their phosphate content without any return. The surface soil however contains a fair amount.

Turning now to Table I the above general deductions can be confirmed in more detail by examining the individual data of various depths. In the fallow plot the phosphate content goes down slowly up to seventh 3-inch layer, and then its concentration remains practically constant except for a slight rise in 17th and 18th layers. In the superphosphate plot the application of the phosphatic fertilizer has increased the phosphate content of the surface 9 in. of soil only, the highest being at the surface 3 in.; and below, the phosphate content decreases slowly, reaching in the 4th layer the level of the corresponding layers of the other plots. It is thus evident that the penetration of the phosphate applied at the surface soil takes place up to the surface 9 in. only. This is in agreement with the observations of Crawley [1902], Thor [1933] and other workers.

From 12 in. to 36 in. the phosphate content gradually goes down. In the next 9 in. from 36 in. to 45 in., it rises and varies inversely as the $CaCO_3$ which reaches the minimum concentration.

Except for the surface 9 in. and 12th to 15th soil layers the phosphate content of the potassium sulphate plot is generally lower than that of the corresponding soil layers of the fallow plot. The superphosphate plot too behaves in this way from 18 in. below the surface. This is demonstrated in Fig. 1 along with the inverse relationship between $CaCO_3$ and P_2O_5 contents.

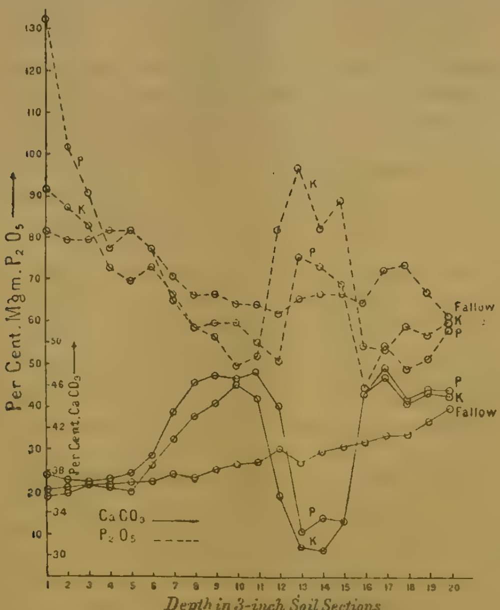

FIG. 1. The relationship between $CaCO_3$ and P_2O_5 contents of 3-inch vertical soil sections of a calcareous Pusa soil

It is conceivable that in the soil layers where the $CaCO_3$ content is high the proportion of the actual soil containing phosphate and other acidic and basic constituents and playing an active part in crop production must be less than in the soil layers where the percentage of $CaCO_3$ is comparatively low, on the assumption that the natural calcareous soil is, as it were, an admixture of soil and $CaCO_3$. As a corollary to this, the inverse relationship between $CaCO_3$ and P_2O_5 contents may take place as shown by the experimental results. This relation is not, however, regular which shows that other factors, such as, cropping and fertilizer practices, climatic conditions, or even the natural processes which took part in the formation of these calcareous soils from their parent rocks, may have influence on this relation.

Summary

As a result of phosphate fertilization, the concentration of phosphate increases only in the surface 9 in. of a calcareous soil. This indicates that phosphate remains mostly where it is placed in the soil.

Phosphate concentration in the different vertical soil layers of a calcareous soil varies inversely as the corresponding $CaCO_3$ concentration. This relation is not, however, uniform in character.

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DISTRIBUTION OF SOIL MOISTURE UNDER CROP AND ITS RELATION TO YIELD

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FOR developing sound cropping schemes, a knowledge of the water requirements of the crops and the depth from which these obtain their water supply is of great importance. Such information will be of great help in evolving judicious methods of irrigation for the tracts, where irrigation facilities are available and for selection of crops for dry-farming tracts. With this idea in view, the study was started at the Dry Farming Research Station, Rohtak. The work reported by Kanitkar [1944] from Sholapur shows that there exists a high correlation between the total yield of crops and the total available water which is equal to the available moisture present at the time of sowing and the rainfall received after sowing of the crop. More detailed work has been carried out in the United States. Cole and Mathew [1923] while determining the use of water by spring wheat in the great plains came to the conclusion that from the amount of soil moisture present in the surface layer, at the time of seeding, it is possible to forecast the yield of spring wheat. This determination helps in deciding whether the crop should be sown or omitted from the crop system. Finnell [1929] from his studies has concluded that it is not only the moisture in the surface soil which determines the yield of the crop but sub-soil moisture also is of far reaching importance. He also concluded that though from the moisture present at the time of seeding, yields of *Sorghum* could be predicted but no valuable information could be obtained with regard to wheat. As these investigations were carried out at two different localities, there is nothing strange, if the results from both the localities were not comparable. These observations however suggest that the findings from a certain locality are not of universal application and in order to find out results of practical importance for a particular locality these are to be worked out in that locality.

Experimental

Four different crops (1) *bajra* (*Pennisetum typhoideum*), (2) *guara* (*Gyamopsis psoralioides*), (3) *gram* (*Cicer-arietinum*), and (4) wheat, were included in the study and water removed by them at different stages of their growth was found out. As these crops got almost entire supply of their water from six feet column of soil, therefore moisture was estimated down to a level of six feet, before sowing and after harvesting of crops and of varying depths in between these two dates. The data reported in each case are average values of 12 to 18 individual determinations.

Bajra. Distribution of moisture under this crop was studied during the years 1937, 1939, 1940 and 1941. In the year 1937 moisture was estimated at fortnightly intervals, and in the following years, the interval was increased to one month. Results are given in Table I.

The season during which observations were made greatly differed from year to year. In the year 1939 rains were much below the normal and therefore the crop instead of depending on the rains of the season, had to draw moisture from the soil reserve. On 20-7-1939 a month after the sowing of the crop, the crop had drawn moisture from three feet column of the soil. On 18-8-1939 the crop had further removed moisture and decreased it to 6·44 per cent from 9·19 per cent on 20-7-1939 in three feet column of soil. Later on there were further losses though small in amount. The moisture in the first foot had fallen below the wilting coefficient on 18-8-1939 and later, on 13-10-1939, it had gone even below the hygroscopic coefficient. The crop during this year removed moisture from the entire six feet layer of the soil. In the year 1937 though the summer rains were about the normal and nearly double of those in 1939, the rainfall in the month of August was only 1·20 in. against a normal of 3·72 in. There was no decrease in moisture till the end of July and the crop depended

* The work was carried out at Dry Farming Research Station, Rohtak.

for the water supply on the rains of the season, but in August there was a sudden demand on moisture present in the soil which fell from 12·52 per cent on 7-8-1937 to 6·96 per cent on 18-8-1937, in three feet column of the soil. Moisture in the first foot layer on 18-8-1937 had fallen below the wilting co-efficient. There was a further decrease in the moisture in the lower layers and at the time of harvesting there was a decrease of moisture in the entire six feet column of soil.

TABLE I

Moisture as percentage on oven dry soil (Bajra)

1937

	1-7-1937	24-7-1937	7-8-1937	18-8-1937	3-9-1937	21-9-1937	15-10-1937
Rainfall in inches	..	3·98	2·37	0·24	0·96	2·69	..
Depth—							
0-6 in.	13·00	10·86	10·00	3·52	5·02	9·49	3·56
6-12 in.	12·55	12·51	11·07	5·54	3·41	10·64	5·73
2nd ft.	12·66	14·50	13·02	7·33	6·99	7·85	7·53
3rd ft.	13·91	14·93	14·02	9·01	8·35	7·80	7·61
4th ft.	14·22	..	..	..	..	..	8·14
5th ft.	14·90	..	..	..	..	..	10·80
6th ft.	15·45	..	..	..	..	..	11·84
Average	13·99	13·70	12·52	6·96	7·02	8·57	8·38
Average for 3 ft.	13·12	13·70	12·52	6·96	7·02	8·57	6·59

1939

	20-6-1939	20-7-1939	18-8-1939	14-9-1939	13-10-1939	20-10-1939
Rainfall in inches	..	1·72	0·91	0·81	..	..
Depths—						
0-6 in.	11·00	10·56	3·08	3·14	2·10	1·93
6-12 in.	11·43	10·53	4·96	4·76	3·18	4·57
2nd ft.	10·00	8·32	6·60	5·81	6·27	6·32
3rd ft.	11·30	9·02	8·71	7·47	7·73	7·94
4th ft.	12·17	..	..	..	..	8·65
5th ft.	11·68	..	..	..	..	8·57
6th ft.	10·83	..	..	..	..	8·73
Average	11·20	9·29	6·44	5·74	5·55	7·24
Average for 3 ft.	11·84	9·29	6·44	5·74	5·55	5·84

1940

	9-7-1940	13-8-1940	13-9-1940	26-9-1940	6-10-1940
Rainfall in inches	..	5·38	2·26	1·09	.
Depths—					
0-6 in.	12·50	18·00	3·49	12·80	7·24
6-12 in.	12·11	16·59	6·47	10·00	8·29
2nd ft.	11·72	16·00	9·70	9·00	9·46
3rd ft.	13·20	14·48	11·79	12·57	11·64
4th ft.	15·10	..	13·59	14·89	13·98
5th ft.	16·43	..	..	16·09	15·95
6th ft.	16·09	..	..	17·00	16·88
Average	14·14	15·93	10·01	13·51	12·61
Average for 3 ft.	12·41	15·93	8·82	11·02	9·62

Table I—*contd.*

Moisture as percentage on oven dry soil (Bajra)

1941

	13-7-1941	14-8-1941	29-8-1941	14-9-1941	4-10-1941	12-10-1941	13-10-1941
Rainfall in inches	..	4·32	0·62	2·60	..	..	..
Depths—							
0-6 in.	4·91	10·51	5·49	12·45	2·38	1·88	1·44
6-12 in.	6·84	10·38	8·57	11·74	5·21	4·58	2·56
2nd ft.	8·43	8·32	8·57	8·78	7·67	6·95	5·34
3rd ft.	7·76	7·86	8·31	8·46	8·55	8·71	6·99
4th ft.	9·14	9·07	..	9·92	9·58	9·68	9·88
5th ft.	10·12	..	..	10·18	10·13	10·48	9·54
6th ft.	8·74	..	..	..	..	9·31	8·43
Average	8·18	8·92	7·97	9·89	7·94	8·06	7·03
Average for 3 ft.	7·02	8·87	7·97	9·78	6·67	6·29	4·78
Hygroscopic coefficient							
	0-6 in.	6-12 in.	2nd ft.	3rd ft.	4th ft.	5th ft.	6th ft.
	3·03	3·70	4·41	3·89	3·69	3·79	4·12
Wiltig coefficient							
	4·46	5·45	6·52	5·58	5·26	5·40	5·86

The rains in the years 1940 and 1941 were about normal and well distributed. In these years there was a very small decrease in the soil moisture till the middle of August, but later on the demand increased and the crop got its water supply from the moisture originally present in the soil. In the year 1940 when August rains were more copious and well distributed, the crop got its water supply from the first four feet column of soil while in the year 1941 when August rains were less and had stopped by the middle of the month, the crop removed moisture from the whole six feet column of the soil.

These results indicate that during normal years, moisture under *bajra* crop remains more or less the same as is present at the time of sowing of the crop till the middle of August but afterwards when *bajra* begins to flower and seed formation starts, it draws water from the moisture conserved in the soil. The depth from which it gets its water varies with the season but generally it draws its water from the entire six feet column of the soil though about 75 per cent of the total water required by it comes from the first three to four feet layer.

Guara. Distribution of moisture under *guara* was determined in the year 1940 when it was sown in a randomized experiments with *bajra*. Therefore the results obtained from the plots under both the crops are comparable. Distribution of moisture on different dates is given in Table II.

Table II

Moisture as percentage on oven dry soil

	5-7-1940	15-8-1940		13-9-1940		13-10-1940		14-11-1940	
		Cropped	Fallow	Cropped	Fallow	Cropped	Fallow	Cropped	Fallow
Rainfall in inches	..	..	5·56	..	2·26	..	1·09	..	..
Depth									
0-6 in.	10·4	16·4	19·8	3·8	7·0	3·4	6·3	3·0	6·9
6-12 in.	8·0	15·7	16·9	5·6	13·4	6·0	12·1	5·4	11·2
2nd ft.	9·7	15·4	16·1	8·1	14·8	7·5	14·6	7·1	14·4
3rd ft.	10·1	11·5	16·5	9·0	16·9	9·8	15·4	8·1	15·4
4th ft.	10·4	..	..	10·6	18·6	10·3	15·0	10·2	..
5th ft.	11·2	..	..	..	..	11·8	16·2	11·1	..
6th ft.	11·9	..	..	..	..	..	..	12·6	..
Average	10·4	14·34	16·98	8·08	15·13	8·68	14·08	8·88	..
Average for 3 ft.	9·67	14·34	16·98	7·27	13·97	7·34	13·07	6·47	12·97

From 5-7-1940, the date on which crop was sown till 15-8-1940 there was no loss of moisture from the soil but there was increase of 4·67 per cent of moisture in three feet column of soil due to 5·56 in. of rain received during the interval. From 15-8-1940 to 13-9-1940, there was a loss of 7·07 per cent of moisture from cropped plots in a three feet layer. From 13-9-1940 to 13-10-1940, there was no apparent loss from the cropped plots while from the fallow plots, there was a loss of 0·97 per cent. From 13-10-1940 to 14-11-1940, there was a loss of 0·97 per cent moisture from the cropped plots, while from the fallow plots there was only a loss of 0·1 per cent. From the fallow plots losses occurred only from the first foot while from the cropped plots there was loss of moisture from each layer down to four feet.

When distribution of moisture under both the crops is compared, it is observed that in earlier periods more moisture was removed by *bajra* than *guara*. The total moisture removed by *bajra* was slightly more than that by *guara*. *Guara* removed comparatively more moisture from the lower layers and it was between 13-10-1940 and 14-11-1940 that it tapped moisture from the third foot, a period during which it was forming seed.

Gram. Distribution of moisture under this crop was studied during the years 1936-1937, 1940-1941 and 1941-1942. The results are given in Table III.

TABLE III

Moisture as percentage on oven dry soil (Gram)

	27-9-1936	17-10-1936	30-10-1936	20-11-1936	7-12-1936	26-12-1936	11-1-1937	27-1-1937	27-2-1937	15-3-1937	27-3-1937
					Cropped plots						
Rainfall in inches	..	..	..	..	0·34	0·52	..	..	4·31	..	0·20
Depth—											
0-6 in.	10·17	6·97	7·91	6·24	7·27	7·80	5·54	4·87	11·13	8·06	6·74
6-12 in.	13·55	8·76	10·91	8·55	9·02	10·32	8·31	7·53	14·04	12·51	12·17
2nd ft.	15·60	13·86	14·09	12·40	12·60	13·00	11·52	11·78	14·91	14·02	15·77
3rd ft.	16·21	15·42	14·99	14·45	14·02	14·23	13·14	13·45	14·77	14·22	14·88
4th ft.	15·06	..	..	..	..	..	..	..	..	..	14·91
5th ft.	15·60	..	..	..	..	..	..	..	..	..	15·51
6th ft.	16·42	..	..	..	..	..	..	..	..	..	16·13
Average	15·13	12·38	12·83	11·42	11·56	12·09	10·55	10·48	14·09	12·84	13·34
Average for 3 ft.	12·38	12·83	12·83	11·42	11·56	12·09	10·55	10·48	14·09	12·84	13·33

	29-10-1940	27-11-1940	27-12-1940	27-1-1941	3-3-1941	31-3-1941
			Cropped plots.			
Rainfall in inches	..	..	..	2·42	0·59	0·15
Depth—						
0-6 in.	5·05	3·73	4·16	11·77	[illegible]	2·05
6-12 in.	9·23	6·95	6·79	12·88	8·26	5·88
2nd ft.	11·75	10·22	10·78	11·86	10·32	8·11
3rd ft.	12·45	11·83	12·46	11·68	11·68	10·67
4th ft.	13·92	..	..	..	12·99	12·53
5th ft.	14·88	..	..	..	13·15	14·18
6th ft.	15·79	..	..	..	..	15·17
Average	12·65	9·13	9·57	11·95	10·98	10·77
Average for 3 ft.	10·45	9·13	9·57	11·95	9·58	7·58
			Fallow plots			
Rainfall in inches						
Depth—						
0-6 in.	6·53	4·95	4·38	13·93	8·61	6·03
6-12 in.	11·61	10·59	9·05	14·47	12·83	11·00
2nd ft.	14·52	13·38	14·27	14·66	14·14	13·52
3rd ft.	15·65	16·26	15·87	16·90	15·51	16·80
4th ft.	15·61	..	..	..	17·97	16·67
5th ft.	16·12	..	..	..	20·79	17·24
6th ft.	..	..	..	..	..	..
Average	13·97	12·44	11·98	15·25	15·46	12·95
Average for 3 ft.	13·08	12·44	11·98	15·25	[illegible]	15·41

TABLE III—*contd.*

Moisture as percentage on oven dry soil (Gram)—contd.

	18-10-1941	19-11-1941	16-12-1941	19-12-1941	9-1-1942	26-1-1942	24-2-1942	14-3-1942	25-3-1942
					Cropped plots				
Rainfall in inches	..	..	..	0·21	..	1·01	1·68	..	..
Depth—									
0-6 in.	4·38	4·31	3·90	3·89	3·51	6·91	9·63	4·11	2·38
6-12 in.	8·70	7·56	7·18	6·06	7·83	8·92	10·41	7·76	5·57
2nd ft.	12·02	10·49	10·01	10·88	11·11	9·49	9·80	9·02	8·55
3rd ft.	11·06	10·33	9·83	10·97	11·04	10·06	10·15	10·23	10·44
4th ft.	11·42	..	..	11·87	12·04	11·50	11·83	11·22	11·88
5th ft.	12·90	..	..	..	13·41	12·32	13·04	12·48	12·55
6th ft.	12·02	..	..	..	10·54	11·84	11·26	11·27	11·40
Average	10·99	8·92	8·47	9·68	10·64	10·52	11·02	10·03	9·80
Average for 3 ft.	9·87	8·92	8·47	8·94	9·27	9·16	9·99	8·40	7·66
					Fallow plots				
Rainfall in inches									
Depth —									
0-6 in.	5·15	3·98	3·08	3·90	3·28	7·22	13·67	7·30	4·50
6-12 in.	7·84	8·23	7·96	6·94	8·31	8·45	12·91	10·93	8·18
2nd ft.	12·06	12·10	12·37	11·15	12·16	10·89	11·41	12·14	11·60
3rd ft.	11·67	12·66	12·42	11·11	12·74	11·91	12·89	12·07	12·41
4th ft.	10·87	..	..	10·59	11·37	12·20	12·54	11·49	12·53
5th ft.	9·20	..	..	..	10·69	10·89	10·21	10·71	10·71
6th ft.	8·08	..	..	..	8·27	8·39	10·01	8·45	9·39
Average	9·88	10·29	10·10	9·59	10·17	10·69	11·64	10·67	10·50
Average for 3 ft.	10·08	10·29	10·10	9·23	10·23	10·21	12·35	11·11	10·12

The results obtained 20 to 30 days after the sowing of the crop show, that there was fall in moisture in the whole three feet column of soil, the fall being more in the surface foot than in the lower layers. Later on losses were very small and gradual, the losses being more from the lower layers than from the surface foot. About the middle of January, demand of the crop for water increased and it removed moisture from the second and the third foot. From about the end of January till the end of February or beginning of March the losses of moisture from the soil were small and gradual. Later on demand of the crop for water greatly increased and there was a big fall in the entire six feet column of soil ; the decrease being more in the upper three feet layer than in the lower three feet.

Moisture in the first six inches was reduced below the hygroscopic coefficient while in the second six inches, it was about the wilting coefficient and in the fallow plots moisture was always higher than the cropped plots and it was generally above the wilting coefficient. Increase in moisture due to rains was more in the fallow plots than in the cropped ones.

Wheat.—Movement of moisture under this crop was studied during 1936-1937 and 1938-1939. The results are given in Table IV.

TABLE IV

Moisture as percentage on oven dry soil

1937

	30-10-1936	12-11-1936	27-11-1936	12-12-1936	12-1-1937	19-2-1937	5-3-1937	19-3-1937	3-4-1937	20-4-1937
Rainfall in inches	..	..	0·34	0·52	4·22	..	..	.	..	..
Depth—										
0-6 in.	6·52	3·98	4·46	4·77	4·05	12·68	4·67	3·47	4·32	2·33
6-12 in.	9·50	6·21	5·74	7·10	6·24	11·19	8·16	5·89	5·71	4·57
2nd ft.	11·81	9·83	8·05	9·02	9·67	12·93	10·66	7·85	7·49	5·18
3rd ft.	12·19	11·86	10·33	11·21	11·22	11·00	11·50	9·76	8·47	6·04
4th ft.	11·01	10·80	..	..	11·28	10·33	9·89	9·60	9·67	7·99
5th ft.	10·70	9·74	..	..	9·76	10·28	12·20	9·34	..	9·71
6th ft.	10·16	9·25	..	..	9·82	9·07	9·20	10·33	..	9·72
Average	10·80	9·43	7·83	9·02	9·48	10·93	9·97	8·59	7·66	7·01
Average for 3 ft.	10·67	8·93	7·83	9·02	8·68	11·06	9·52	7·43	6·99	4·89

1938

	17-11-1938	18-11-1938	19-12-1938	19-1-1938	18-2-1938	19-2-1938	17-4-1938
Rainfall in inches	..	..	..	..	0·40	2·46	0·55
Depth—							
0-6 in.	13·34	11·69	8·55	5·39	7·03	6·34	4·09
6-12 in.	15·00	14·04	11·88	7·47	9·52	8·58	6·51
2nd ft.	16·93	13·83	13·35	10·65	10·02	9·77	9·20
3rd ft.	16·18	..	12·85	11·69	11·66	11·04	10·83
4th ft.	14·72	..	..	..	11·23	9·65	10·14
5th ft.	13·63	..	..	..	11·79	11·82	12·86
6th ft.	13·37	..	..	..	..	11·82	13·63
Average	14·83	13·35	12·13	9·59	10·59	10·26	10·51
Average for 3 ft.	15·76	13·35	12·13	9·59	9·98	9·42	8·44

Distribution of moisture under wheat is more or less similar to that under gram. First sampling after sowing was done after 12 days when germination was almost complete. The results show that there was considerable fall in moisture during this period. There was fall of moisture in the entire six feet column of the soil, though considerable loss occurred from the first two feet. Later on fall in moisture was gradual and small from the first three feet layers till the beginning of March when losses became large. This period coincides with flowering and seed formation in wheat. During this period also, considerable losses only occur from the first three feet : the losses from the lower layers are small ; and insignificant.

In the year 1938-1939 there were no rains and the fields were irrigated for sowing of the crop. Therefore there was a higher status of moisture in these fields than is generally found under dry farming. As the moisture in the year 1938-1939 was at a higher level than in the year 1936-1937, there were losses in the year 1938-1939, especially from the first two feet layer.

DISCUSSION

Distribution of moisture and the yield of the crop

Kharif *crops*. *Kharif* crops put on more of vegetative growth than *rabi* crops (Tables V and VI) and therefore to sustain these more water is required. In case of drought, it is the *kharif* crops which suffer more. Out of the two *kharif* crops *bajra* and *guara*, it is the former which suffers more, on

account of its larger vegetative growth. In order to maintain its heavy vegetative growth, *bajra* taps the lower layers for water even in the early stages of its growth (Table I). During August when the crop starts seed formation, its need for water increases and water in the soil is not enough to meet its requirements. If in August rains fail, *bajra* crop begins to dry up and the grain yield becomes very poor. On the other hand, *guara* does not put on large vegetative growth and to maintain this amount of vegetative growth, it generally depends on the moisture in the upper layers and when extra water is required for seed formation, it taps the lower layers and thus forms the seeds. *Guara* therefore forms seeds even in conditions in which rains are low and which *bajra* fails to form grain. The above conclusions have the support of the yield data. Yield of both the crops along with the moisture data are given in Table V.

TABLE V

Yield of crops and the moisture data

	1936	1937	1938	1939	1940	1941	1942
Bajra.							
Moisture in three feet column of soil before sowing							
	9·74	10·88	6·23	8·17	9·99	7·96	9·43
Yield in pounds per acre							
Grain	1017	512	*Nil*	135	828	512	968
Straw	3194	2768	123	1947	3030	1515	2975
Guara							
Moisture in three feet column of soil before sowing							
	11·91	9·92	6·69	6·64	8·36	7·30	9·33
Yield in pounds per acre.							
Grain	1296	981	220	553	648	619	1366
Straw	3588	..	..	..	..	950	..
Rainfall in inches in August	6·31	1·20	1·68	1·01	6·46	4·34	7·16
Total summer rainfall	17·55	12·92	6·73	7·40	10·91	13·17	25·47

From the above results it is observed that *guara* has been giving more yield of grain than *bajra* except in the year 1940. In 1940 though the total rain-fall was slightly less than the normal, August rains were double the normal and therefore *bajra* gave higher yields. Yields of straw for *guara* are available only for the year 1936 and 1941. In the year 1936, the rains were above normal and well distributed while in the year 1941 rains were about normal and were not so well distributed as in the year 1936. In the year 1936, grain to straw ratio in the case of *guara* was larger while in the year 1941 it was smaller. In the case of *bajra* reverse is the case. In the years 1936, 1941 and 1942, when the rains were normal or rather above the normal, the grain to straw ratio was narrow, while in the years 1937, 1938 and 1939, when August rains were defective, the grain to straw ratio was larger and the yield of grain poor. These results are in accordance with the distribution of moisture already discussed. *Bajra* puts on a large amount of vegetative growth and to maintain it, it has to tap the lower layers and therefore in the month of August when grain formation starts, *bajra* badly stands in need of water. On the other hand, *guara* in the years of low rainfall or when there is low moisture in the soil, decreases its vegetative growth to such an extent that it can be maintained with the water stored in the upper two feet layer and, at the time of seed formation, it draws more water from the lower layers and therefore its yield is more than that of *bajra*.

Correlations have been worked out between the moisture present before sowing, rainfall in August, total rainfall and the yield of the crops. The correlation is not significant between the yield of *bajra* grain and moisture at the time of sowing but it is significant between the yield and the rains in August (0·8852) or the total rainfall (0·8120). On the other hand, correlation between the yield of straw and moisture present at the time of sowing is significant (0·7363), while the other two correlations are not significant. These results indicate that moisture at the time of sowing influences the yield of straw and not that of grain.

Correlations of these factors with regard to the yield of *guara* grain show that there is a significant effect of moisture at the time of sowing (0·8505) and the total rainfall (0·9072) on the yield, but there exists no such correlation between the rains in August and the yield.

These calculations support the observations already made that for obtaining normal yield of *bajra* grain, August rains are very essential but these are immaterial for *guara*.

Rabi *crops*. The yield of both the crops along with moisture present at the time of sowing and winter rainfall are given in Table VI.

TABLE VI

Yield of gram and wheat, moisture at the time of sowing and winter rainfall

	1936-1937	1937-1938	1939-1940	1940-1941	1941-1942	1942-1943
Gram						
Moisture in three feet column of soil before sowing	14·01	12·50	8·51	12·00	9·85	14·12
Yield in lb. per acre						
Grain	1588	788	89	837	395	1562
Straw	2355	880	..	824	402	1490
Wheat						
Moisture in three feet column of soil before sowing	13·36	11·61	7·60	11·14	9·85	13·79
Yield in lb. per acre						
Grain	1497	632	390	520	246	1046
Straw	1971	1071	475	673	324	1036
Rainfall in inches December and January	0·86	1·51	..	0·98	2·42	1·22
Total winter rainfall	5·37	1·52	3·41	5·80	3·46	2·90

Gram puts on more of vegetative growth than wheat and therefore there has always been more of gram straw than wheat straw and, in order to maintain it, it draws more moisture from the soil than wheat. In the year 1939-1940 when there was low moisture in the soil and there were no early winter rains, gram crop totally failed and gave very poor yield of 89 lb. per acre but that of wheat was 390 lb. per acre. In other years when there were early winter rains, gram grain was more than wheat grain.

Correlations between the moisture present at the time of sowing and the yield of gram grain (0·9819) and gram straw (0·9006) are significant and those between moisture present and wheat grain and wheat straw are not significant. There exist no significant correlation between the rains received in December and January and the yields. In the case of total winter rains there is a high correlation between these and the yield of wheat grain (0·8810) but there is no such correlation with regard to the yield of gram crop.

These results show that gram crop for its water requirement depends mainly on the moisture conserved in the soil. When moisture in the soil is low, early showers of the winter rains in the end of December or beginning of January are essential. On the other hand, wheat does not depend so much on the moisture conserved in the soil as gram and winter rains are of great use for producing a normal wheat crop.

These results further suggest that the yield of *guara* and gram can be predicted with fair accuracy from moisture present at the time of sowing.

Summary

In the early stage of growth, *kharif* crops (*bajra* and *guara*) generally depend on the rains and moisture in the soil remains more or less the same as at the time of sowing till the middle of August. After the middle of August the crops draw moisture from the soil and more water is drawn by *bajra* than *guara*. In order to get a normal yield of *bajra* grain, rains in August are a necessity. However, *guara* at the time of seed formation obtains moisture from the deeper depths and therefore in the years of defective rainfall the yield of *guara* is more than that of *bajra*.

About 20 days after the sowing of *rabi* crops (wheat and gram) there is considerable fall in moisture, decrease being more from the first two feet than the lower layers. Later on fall in moisture is gradual and small in amount. From the end of February or the beginning of March the demand of the crop for water increases and there is considerable decrease of moisture in the entire six feet.

A high correlation exists between the moisture at the time of sowing and the yields of *guara* and gram, but no such correlation exists in the case of the yields of *bajra* and wheat. A correlation between the winter rains and the yield of *rabi* crops shows that winter rains are beneficial for the formation of wheat grain but they do not influence the yields of gram, which are mainly dependent on the moisture conserved in the soil.

A high correlation exists between the August rains and the yield of *bajra* and it shows that for a normal yield of the crop, August rains are a necessity.

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POT CULTURE EXPERIMENTS ON THE MANURIAL VALUES OF COMPOSTED AND UNCOMPOSTED MATERIALS*

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MANURIAL trials in field plots as well as in pot cultures, using composts prepared by different methods and uncomposted materials, were carried out in the Experimental Farm attached to the Indian Institute of Science, Bangalore, during the period 1938-1941. The main results obtained in the pot culture studies are presented in this paper.

Materials and methods

The soil used for the pot cultures was a local red-loam of physical and chemical composition as shown in Table I.

Table I

Analysis of soil used for pot cultures

Mechanical composition		Chemical composition	
Coarse sand	33·4 per cent	Total carbon	0·59 per cent
Fine sand	26·4 ,,	,, nitrogen	0·058 ,,
Silt	7·7 ,,	,, P_2O_5	0·02 ,,
Clay	26·4 ,,	,, K_2O	0·22 ,,
Moisture	3·84 ,,	,, lime (CaO)	0·10 ,,
Loss on ignition	3·19 ,,	Silica (SiO_2)	77·76 ,,
Carbonate	*nil*	Iron and alumina ($Fe_2O_3+Al_2O_3$)	13·75 ,,
*p*H	6·2 ,,		

It would be noted that the soil is poor in phosphoric acid, but contains average amounts of nitrogen and carbon for Indian red-loams.

Twenty lb. of the above soil were well mixed with 10 lb. of washed sand and added to each pot. The manure selected for trial was mixed uniformly with the surface layer of soil to a depth of five to six inches, after which water was added and the manure was allowed to decompose in the soil for a period of two to three weeks before the crop was sown. Each treatment was replicated six times and the pots were kept in six parallel blocks; and within each block the individual positions of the pots were randomized.

Two crops were tried, viz. *ragi* (*Eleucine coracana*) and *jowar* (*Andropogan sorghum*). *Ragi* was grown as the first crop and *jowar* as the second crop in the same pots—the latter in order to assess the residual values of the manures. *Ragi* was transplanted into the pots from a seed-bed when 20 days old; four seedlings of the same height and vigour were distributed to each pot and these were thinned to three plants after about 10 days. The pots were watered every day till shortly prior to harvest. The grain and plant tissues were weighed separately.

After the *ragi* was harvested, the soil in the pots was well stirred and the root system was allowed to decompose for five to six weeks, with moistening of the soil from time to time. After this period, *jowar* was grown as a fodder crop. Four seeds were sown in each pot and the seedlings were thinned down to two after a fortnight. The *jowar* was removed at the flowering stage, dried and weighed.

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Series I

Comparison of different types of composts

The first series of trials was devoted to a comparison of composts prepared from different types of refuse material, viz. (a) compost prepared from mixed vegetable refuse, to which only a small quantity of cattle dung was added as starter; (b) compost prepared from town refuse and night-soil; (c) a poudrette prepared by mixing night-soil with wood-ash; (d) a sample of farmyard manure obtained locally; and (e) ammonium sulphate. Including the untreated 'control' pots, there were six treatments in all. The analyses of the different manures used, in regard to their content of carbon and nitrogen are given in Table II. The manures were applied on enquivalent nitrogen basis, at the rate of one gram of nitrogen per pot. The yields of the first crop of *ragi* (grain and straw) and the succeeding crop of *jowar* are given in Table III.

TABLE II

Analysis of manures used (on dry basis)

Manure	Carbon	Nitrogen	C/N ratio
	Per cent	Per cent	
I. Compost from mixed farm refuse	10·14	0·98	10·35
II. Compost from town refuse and night-soil	13·26	1·26	10·52
III. Wood-ash and night soil poudrette	11·12	1·32	8·43
IV. Farmyard manure	14·96	1·38	10·84

TABLE III

Comparison of different manures (mean yield per pot—dry matter)

Manure applied (one gm. nitrogen per pot)	Ragi			
	Grain (gm.)	Straw (gm.)	Total dry matter (gm.)	*Jowar* fodder (dry weight). (gm.)
A Control (unmanured)	5·42	8·25	13·67	15·43
B Farm refuse compost	8·38	12·15	20·53	24·47
C Town refuse and night-soil compost	9·62	14·78	24·40	32·70
D Night soil and wood-ash poudrette	12·58	21·12	33·70	37·10
E Farmyard manure	9·23	15·45	24·68	28·47
F Ammonium sulphate	8·18	11·87	20·05	19·47
Critical difference ($P = 0·05$)	2·81	3·01	4·76	5·14

It would be noticed that all the manures tried (B to F) have given significantly higher yields of crop than the unmanured control soil (A). In regard to *ragi* grain, the compost prepared from mixed farm refuse (treatment B), compost prepared from town refuse and night-soil (treatment C), farmyard manure (E), and ammonium sulphate (F) have given similar increases of yield, whereas the poudrette prepared by admixture of wood-ash with night-soil (treatment D) stands out significantly superior to any of the other manures.

The increases in yields of *ragi* straw in the first season and of *jowar* in the succeeding season are also highly significant for all treatments. These stand in the ascending order of effectiveness as follows: ammonimum sulphate, compost from farm refuse, compost from town refuse and night-soil, farm-yard manure and finally poudrette from night-soil and wood-ash. All the manures, except ammonium sulphate, leave a highly significant residual effect in the soil, and the extent of the residual effect in the second season is in general proportional to the manurial efficiency of the product as shown in the first season.

A comparison of the analytical figures given in Table II with the yield data presented in Table III would show that even though all the manures have been applied on equal nitrogen basis and though the C/N ratios of the composts prepared from mixed farm refuse (treatment B) and from town refuse and night-soil (treatment C) are similar to the C/N ratio of farmyard manure (E), definite differences are observed in the manurial values of the three products. The compost prepared from town refuse and night-soil (C) is equal in efficiency to farmyard manure, whereas the compost prepared from mixed farm refuse low in dung (B) appears to be somewhat poorer in quality. This difference is possibly due to the fact that both farmyard manure and compost (C) were prepared from raw products rich in nitrogen, viz. night-soil in the one case and cattle dung and urine in the other, whereas compost (B) had been prepared from a main bulk of vegetable refuse to which only a small quantity of dung was added as starter. It would thus seem that the C/N ratio of a compost product can by itself give no reliable indication of its manurial efficiency ; but it would be necessary to know also the mature and quantities of the refuse materials used in the preparation of the compost.

The outstanding superiority of manure D (wood-ash plus night-soil poudrette) is presumably due to the additional effect of the phosphoric acid (contained in wood-ash) superimposed on the beneficial effect of nitrogen contained in night-soil. The red-loam soil used in the present studies being poor in phosphoric acid, the effect of added phosphoric acid has been considerable. That the effect was not appreciably due to correction of soil acidity by lime contained in wood-ash was shown by other crop experiments (not included in the present paper) wherein lime and superphosphate were added separately to the soil under examination.

Series II

Influence of uncomposted materials on plant growth

The results obtained at Rothamsted [Annual Reports, 1935-1939] and at Tocklai [Cooper, 1939] indicate that, under favourable conditions, uncomposted refuse materials could be directly applied to land, with beneficial results on plant growth equal to, and in some cases even superior, to those obtained by application of compost manure prepared from the above refuse. At Rothamsted, straw supplemented by *adco* has been tried, while at Tocklai, mixed farm wastes supplemented by starters such as *niciphos* have been used. The C/N ratios of the uncomposted mixed refuse (along with the starter) used in the above cases were round about 30.

It is well known that green manures with C/N ratios narrower than 20 could be applied directly to land with beneficial results on crop growth. On the other hand, it is also known that materials of wide C/N ratios such as straw (C/N near 80) or sugarcane trash (C/N from 100 to 120) react adversely on subsequent crop growth by lowering the available nitrogen content of the soil. The behaviour of mixtures of different vegetable wastes possessing intermediary C/N ratios, i.e. between 20 and 80 has not however received much attention.

In view of the results obtained at Rothamsted and at Tocklai, it seemed worthwhile to examine the question over a wider range of C/N ratios. The C/N ratios tried were 100, 80, 60, 50, 40, 30 and 20 and these were secured by admixing suitable proportions of sugarcane trash, *katcha* (coarse) grass, mixed fallen leaves, weeds, hongay leaves (all dried and cut into small pieces) and cattle dung, as shown in Table IV.

The quantity of mixed refuse added per pot contained one gram of nitrogen, except in the case of C/N ratios 100 and 80 (treatments B and C in Table IV) wherein it was found possible to add only a quantity of refuse containing about 0·5 gm. of nitrogen, on account of the large bulk of the refuse which had to be added in order to supply even 0·5 gm. of nitrogen. The refuse was well mixed in each case with the top three or four inches of soil in the pot, watered and allowed to decompose in the soil for a period of two weeks, with addition of water from time to time. After this period, *ragi* was transplanted in a manner similar to that in Series I.

TABLE IV

Mixed refuse at different C/N levels

	Air dry materials.						Total C and N taken	
	Sugarcane trash	*Katcha* grass	Fallen leaves	Mixed weeds	*Hongey* leaves	Cattle dung (fresh)	Carbon	Nitrogen
Analysis (on air dry basis, except dung which is on fresh basis).	*Percentages.*							
Carbon	41·0	39·0	28·0	37·0	41·0	7·3	..	..
Nitrogen	0·42	0·50	0·99	2·20	3·10	0·30	..	..
Quantities of constituents taken for obtaining the desired C/N ratio	*Weights in grams*							
(B) C/N 100 :1	125	..	..	..	..	..	51·25	0·525
(C) „ 80 :1	55	40	..	..	..	20	39·5	0·48
(D) „ 60 :1	75	50	12	5	5	20	59·1	1·00
(E) „ 50 :1	50	50	10	10	5	20	50·0	0·99
(F) „ 40 :1	50	20	10	10	10	20	40·4	1·00
(G) „ 30 :1	30	10	10	10	15	20	30·3	1·00
(H) „ 20 :1	..	10	10	15	15	20	19·9	0·99

After *ragi* was harvested, *jowar* was grown as a succeeding crop, in order to test the residual effect of the manures added. The crop yields obtained are given in Table V.

TABLE V

Influence on corp growth of uncomposted mixed refuse at different C/N levels

Manure applied	*Ragi*			*Jowar* fodder (total dry matter) (gm.)
	Grain (gm.)	Straw (gm.)	Total dry matter (gm.)	
(A) Control (no manure)	6·35	9·88	16·23	20·20
(B) Mixed refuse C/N 100 :1	5·03	7·73	12·76	22·38
(C) „ 80 :1	5·58	8·37	13·95	26·87
(D) „ 60 :1	6·15	9·27	15·42	34·73
(E) „ 50 :1	6·88	10·47	17·35	40·13
(F) „ 40 :1	7·76	12·37	20·13	42·77
(G) „ 30 :1	8·92	15·43	24·35	41·37
(H) „ 20 :1	9·95	20·23	30·18	38·77
Critical difference (P = 0·05)	1·77	2·89	3·91	5·21

The data presented in Table V lead to the following inferences :

(1) When the over-all C/N ratio of the mixed refuse is wider than 50 : 1, there is a definite depressing effect on crop yield ; and the depressing effect is greater, the wider the C/N ratio of the mixed refuse added. The lowering of crop yield, however, is not found to be statistically significant in the present experiment. As already explained in an earlier paragraph, the quantity of refuse added at the two levels C/N 100 and 80 represented the addition of about 0·5 gm. of nitrogen only per pot, whereas double that quantity was added at other levels. It is possible that if the quantity of refuse added had been doubled at the above two levels, the lowering of crop yield might have been greater and significant (Table VI). A second factor, probably, was the addition of water at regular intervals to the pots for two weeks after application of manure, which might have promoted rapid decomposition of the refuse and narrowing of the C/N ratio before the crop was sown.

(2) When the C/N ratio of the added mixed refuse is narrower than 50, the harmful effect disappears and is replaced by a beneficial effect on crop growth, which increases with narrower C/N ratios. The beneficial effect is not significant at the C/N level of 40 (treatment F) in the matter of *ragi* grain or straw taken separately ; but becomes significant when the total dry matter produced (grain and straw) is considered. The increases produced in grain and straw become individually quite significant at C/N levels of 30 and narrower, thus confirming the beneficial results obtained at Rothamsted [Annual Reports, 1935-1939] and at Tocklai [Cooper, 1939] when uncomposted refuse was applied at the above C/N level.

(3) As regards the residual values left behind in the soil by the refuse added in the previous season, it would be noted from Table V that the depressing effect of mixed refuse of C/N ratios 100 and 80 persisted only during the first season of application. In the succeeding season, a beneficial result was obtained though not significant. The residual effect was highly significant in the case of the other treatments, especially where the initial C/N ratios of added refuse were narrower than 50 : 1.

Series III

Influence of sugarcane trash supplemented by ammonium sulphate

Series III and IV were devoted to a special consideration of the utilization of sugarcane trash (leaves and tops), of which large quantities (10 to 15 million tons per year) are available in India, but are mostly burnt away.

As the replenishment of the organic matter level of cane soils is an important factor in successful cane cultivation and as the composting of cane trash is a tedious operation extending over several months [Tambe and Wad, 1935], it was considered advisable to examine whether favourable crop yields could be obtained by directly incorporating cane trash into the soil, along with a suitable dosage of ammonium sulphate so as to narrow the C/N ratio of the material to a level, which would overcome the harmful effect produced by application of trash alone.

For this purpose, a series of pots were set up to which were added respectively : (i) no manure (Series A), (ii) 100 gm. cane trash only (series B), and (iii) mixtures of 100 gm. cane trash along with increasing dosages of nitrogen, viz. 0·25 gm.0·5 gm., 0·75 gm. 1·0 gm., 1·25 gm. and 1·5 gm. of nitrogen in the form of ammonium sulphate (series C, D, E, F, G and H). Each series carried six replicates. The C/N ratios of the mixtures added in the different cases are shown in Table VI ; these varied from 97·63 to 21·35—roughly over the same range as the uncomposted refuse mixtures tried in series II (Table V).

In order to promote uniform admixture with the soils the cane trash was cut into small pieces and mixed with the top three or four inches of soil, moistened with water and allowed to decompose for a period of 10 days. After this, the required quantity of ammonium sulphate was added in solution and distributed uniformly over the top surface, which was then stirred up and well mixed. At the end of another five days, *ragi* seedlings were transplanted into the pots. The succeeding details were the same as in the earlier series.

Since the second crop of *jowar*, grown in order to test the residual effect, was badly damaged by insects, the yield data for the first crop of *ragi* only are given in Table VI.

TABLE VI

Influence of sugarcane trash supplemented by ammonium sulphate

Manure applied	C/N ratio	Mean yield of *ragi* per pot		
		Grain (gm.)	Straw (gm.)	Total dry matter (gm.)
(A) Control (no manure)	..	5·93	11·13	17·06
(B) 100 gm. cane trash only	97·63	3·47	5·38	8·85
(C) " 0·25 gm. N as ammonium sulphate	61·19	4·92	7·27	12·19
(D) " 0·5 gm. N	44·57	5·73	9·45	15·18
(E) " 0·75 gm. N	35·04	6·72	12·10	18·82
(F) " 1·00 gm. N	28·87	7·77	15·42	23·19
(G) " 1·25 gm. N	24·56	9·78	19·13	28·91
(H) " 1·50 gm. N	21·35	11·13	23·20	34·33
Critical difference ($P = 0·05$)	..	1·96	2·21	3·61

A comparison of the data presented in Tables V and VI would show that they are in general similar, indicating that at corresponding C/N ratios the observed effects are alike whether the C/N ratio is secured by selective mixing of vegetable refuse of different C/N ratios or by adding artificials to vegetable refuse of wide C/N ratio.

In the present case, it was found that the marked depressing effect on crop yield produced by cane trash alone, can be overcome by the addition of 0·75 per cent of nitrogen on the weight of the trash. This would correspond to narrowing the C/N ratio of the trash to about 35 : 1.

A significant beneficial effect on crop yield is noticed when the nitrogenous supplement added is at one per cent level on the trash or higher. The above one per cent level of added nitrogen gives a C/N ratio of 28·87, which approximately agrees with the C/N ratio of 30 :1, found necessary with mixed vegetable refuse in Series II to give a significant increase of crop yield.

A comparison of the data presented in Table VI treatment F and Table III treatment F, wherein one gram of nitrogen in the form of ammonium sulphate had been added with and without sugarcane trash, would show that the yield of *ragi* grain is more or less similar in both cases, but the yield of straw and of total dry matter are markedly higher where sugarcane trash had been added along with ammonium sulphate (Table VI). The difference is presumably due to the improved physical and biological conditions created in the soil by the addition of cane trash.

SERIES IV

INFLUENCE OF CANE-TRASH SUPPLEMENTED BY OIL CAKE

It is a common practice on sugarcane farms to apply large quantities of oil-cake as manure. It was considered desirable to examine whether a considerable amount of cane trash could not be incorporated into the soil along with the cake, so as to provide bulky organic matter which would improve the physical condition of the soil and react beneficially on crop growth.

For this purpose, a series of pot cultures was run on lines quite similar to Series III, except that hongey cake (containing 4·2 per cent nitrogen and 1·95 per cent P_2O_5) was substituted in place of ammonium sulphate. There were eight treatments (Table VII) as in the last series, with graded doses of hongey-cake so as to provide nitrogenous supplements at the rate of 0·25 gm., 0·50 gm., 0·75 gm., 1·0 gm., 1·25 gm. and 1·50 gm. nitrogen per 100 gm. sugarcane trash added. The cane trash (cut into small pieces) and hongey cake were added to the pots at the same time and well mixed with the top layer of soil, moistened with water and allowed to decompose for a period of two weeks, before transplanting *ragi*. Series III and IV were run simultaneously and in the latter also the second crop of *jowar* had to be discarded on account of a bad insect attack.

The yields of the first crop of *ragi* (grain and straw) are given in Table VII.

TABLE VII

Influence of mixtures of sugarcane trash and hongey cake

Manure applied	C/N ratio	Mean yield per pot of *ragi*		
		Grain (gm.)	Straw (gm.)	Total dry matter (gm.)
(A) Control (no manure)	..	5·23	10·18	15·41
(B) 100 gm. sugarcane trash only	97·63	4·03	6·40	10·43
(C) „ plus hongey cake at 0·25 gm. N	61·19	5·10	9·37	14·47
(D) „ at 0·50 gm. N	44·57	7·25	12·43	19·68
(E) „ at 0·75 gm. N	35·04	9·52	16·07	25·59
(F) „ at 1·00 gm. N	28·87	11·57	19·75	31·32
(G) „ at 1·25 gm. N	24·56	13·52	23·13	36·65
(H) „ at 1·50 gm. N	21·35	15·15	26·03	41·18
Critical difference ($P = 0{\cdot}05$)	..	1·67	2·90	3·19

A comparison of the data presented in Tables VI and VII shows not only general similarity, but also reveals some marked differences in the magnitude of effects produced. While in the case of cane trash plus ammonium sulphate, the latter had to be added at a level 0·75 per cent nitrogen on the trash in order to overcome the depressing effect on succeeding crop growth, and at a level of 1·00 per cent nitrogen in order to obtain a significant increase in crop yield over the untreated soil, in the present series of cane trash plus hongey cake, the addition of the latter at a level of 0·5 per cent nitrogen is sufficient to give a significant increase of crop yield. The above difference in behaviour between ammonium sulphate and hongey cake is explainable as being due to the fact that hongey cake contains a good amount of phosphoric acid (1·95 per cent), which exerts a positive influence on crop yield, supplementary to the effect of nitrogen contained in it.

The influence of the phosphoric acid present in hongey cake is also noticed in the relative ratios of grain/straw in the data presented in Tables VI and VII. It would be noticed that while the ratio is near 0·5 in Table VI it is near 0·6 in Table VII. For each definite weight of straw, the corresponding weight of grain is greater in Table VII than in Table VI.

DISCUSSION

The present pot culture experiments reveal that the C/N ratio of a compost by itself cannot give a reliable indication of its manurial behaviour. Composts possessing C/N ratios near 10 : 1 may vary greatly in their effect on crop yield, depending on the nature of refuse materials that were used in their preparation. Evidently, there appears to be considerable variation in the degree of availability of nitrogen and of phosphoric acid present in composts, even though the C/N ratios may be quite similar. In an earlier paper [Acharya, Parthasarathy and Sabnis, 1945] it was suggested that the above differences in availability of nitrogen may be related to the proportion of $\frac{\text{microbial}}{\text{residual}}$ nitrogen that may be present in composts. Very little work has, however, been carried out in this direction.

The present experiments also indicate that mixed farm wastes could be applied to land directly without prior composting, provided that the C/N ratio of the mixed refuse is 30 or narrower. The advantage of the above procedure would be that the cost and trouble of preparing compost could be avoided, but on the other hand, the cost of application to land may be increased on account of the larger bulk of refuse that would have to be dealt with. In addition, there are other likely disadvantages in applying uncomposted refuse to land, such as the incorporation of a large amount of weed seeds along with the refuse, which might prove a nuisance later on, the possible development

of white-ants (termites) on a large scale in the soil, and a possible depletion of soil moisture on account of the application of large quantities uncomposted dry refuse. All these factors may have a harmful effect on this succeeding crop. Further, the land itself may not be ready to receive odd quantities of refuse that would be collected every day and all such daily collections may have to be stored in some manner till the next sowing season comes in, which would again introduce the same problem of manure preparation. In certain special cases, however, especially in areas under irrigation or heavy rainfall, it may be found feasible to add uncomposted refuse directly to the land and, in such cases, the experimental data presented in this paper would indicate the safeguards, regarding the the C/N ratio of the mixed material, that would have to be adopted.

The practice of ploughing in uncomposted refuse directly into the soil may prove specially feasible in the case of sugarcane lands, which receive heavy manuring with artificials or oilcake, and where at present most of the trash is thrown away or burnt on the ground. Usually 3 to 5 tons of trash per acre are available on such lands and these could be usefully ploughed in, along with a supplement of 30-40 lb. of nitrogen in the form of oil-cake or 40-50 lb. nitrogen in the form of ammonium sulphate, preferably supplemented by some superphosphate. It would be found advisable to plough in the trash soon after the cane season is over and apply the cake or ammonium sulphate shortly before the next crop is planted. This procedure would serve to return to the soil a large quantity of organic matter and thus help to keep the soil in good physical and biological condition.

Summary

1. Pot culture experiments, growing *ragi* and *jowar* on a red-loam soil, were carried out in order to : (a) compare the manurial value of composts prepared from farm and town wastes, against farmyard manure, ash poudrette and ammonium sulphate ; and (b) to examine the effect on crop growth of the application of uncomposted refuse material of different C/N ratios ; for this purpose : (i) mixed vegetable refuse of different C/N ratios and (ii) sugarcane trash along with graded supplements of ammonium sulphate or hongey cake were tried.

2. The manures examined were found to increase crop yield in the following descending order of effectiveness : Poudrette from night-soil and wood-ash, compost from night-soil and town refuse, farmyard manure, compost from mixed farm refuse and lastly ammonium sulphate.

3. All the manures, except ammonium sulphate, left a significant residual effect in the soil.

4. Uncomposted mixed refuse produced a depressing effect on crop growth at C/N levels wider than 50 :1 and yielded significant crop increases at C/N levels of 30 :1 and narrower.

5. The application of uncomposted sugarcane trash to the soil produced a marked decrease in crop yield. The harmful effect could be overcome by the addition of ammonium sulphate at the rate of 0·75 per cent nitrogen on the dry matter of the trash. A significant increase in crop yield over untreated soil could be obtained by increasing the supplement of ammonium sulphate to a level of one per cent nitrogen on the weight of the trash.

6. The increased crop yield obtained by the addition of cane trash along with a supplement of one per cent nitrogen as ammonium sulphate was found to be better than the yield obtained by the addition of the same quantity of ammonium sulphate alone. The difference was attributed to the beneficial effects produced in the soil by the added organic matter.

7. Hongey cake was found to be more effective than ammonium sulphate in overcoming the depressing effect of sugarcane trash on crop yield. The addition of a supplement of cake at the rate of 0·5 per cent nitrogen on the weight of trash was sufficient to give a significant crop increase over the untreated soil. This superiortiy of oil-cake is attributed to the phosphoric acid contained in it.

8. The advantages and draw-backs of applying uncomposted refuse to the soil have been discussed. It is pointed out that, in the case of sugarcane soils, it may be found advisable to plough into the soil all the cane trash left on the field, along with a suitable supplement of oil-cake or ammonium sulphate, applied either along with the trash or at a later stage prior to the sowing of the next crop. It is suggested that this procedure would help to supply a large quantity of organic matter to the soil and thus to maintain the physical and biological conditions of the soil under optimum conditions for sugarcane growth.

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SOME OBSERVATIONS ON THE RUST OF GRAM (*CICER ARIETINUM* L.)

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(With two text-figures)

GRAM rust caused by *Uromyces ciceris arietini* (Grognon) Jacz. is prevalent in several parts of India. In northern India it is common in Bihar, the United Provinces, the Punjab and the North Western Frontier Province. In the warmer districts of the U.P. and in Bihar where the crop matures earlier, the damage caused is not very appreciable but in the cooler northern districts of the U.P., the Punjab and the N.W.F.P., the appearance of the disease often coincides with the maturation period of the pod and badly rusted plants consequently give poor yields. The disease appears to be common in the countries bordering the Mediterranean and in the Balkans.

This rust has not received attention so far at the hands of the pathologists and, excepting for a brief account by Butler [1918], there is hardly any literature on the disease. It was first collected by Grognon at Soane, on the river Loire in France, and named *Uredo ciceris-arietini* by him in 1863 but the telial stage was found by Boyer near Montpellier and named by Jacjewski in the publication by Boyer and Jacjewski [1893]. The earliest record of it for India is by Barclay [1890] who tentatively placed it in *Uromyces pisi.*

The work reported here was undertaken in 1938 with a view to study the life history of the rust and to see if there are varieties of gram that are resistant to its attack. The work had to be ended, however, a year later when the first author was transferred to Cawnpore. Some of the interesting observations made in the course of the study are placed on record in this paper.

MORPHOLOGY OF THE RUST

Uromyces ciceris arietini is a hemiform, the pycnial and the aecial stages being unknown. The uredia are as a rule hypophyllous and scattered, minute, round, pulverulent when mature and cinnamon-coloured. The urediospores are globose to subglobose, loosely echinulate, 20 - 28μ in diameter, yellowish-brown with a rather thick epispore and four to eight germ pores. The telia resemble the uredia but are darker brown ; the teliospores are variable in shape, round, ovate or angular with a roundish, unthickened apex and brown, warty or roughened wall. They measure 18 to 30μ by 18 to 24μ and have a short, hyaline pedicel from which the teliospores get readily detached. They have a single germ pore, which fact and their somewhat deeper coloured epispore distinguish them from the urediospores.

Careful search in gram fields has not revealed any pycnial or aecial stages on the gram plants nor have any weeds been found in the vicinity, bearing pycnia or aecia, which might be considered as stages in the life history of this rust.

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Symptoms of the disease

The rust appears as a rule at the end of February when the plants are about four months old. In rare cases, it has been observed as early as the first week of February. Due to this late appearance of the rust, inoculum for experimental work does not become available early enough, unless some special device is discovered for keeping the spores of the previous season viable. The symptoms which the disease produces are very simple. There is no stunting of growth, witches' broom or hypertrophy. The leaves become crowded with small, round or oval, cinnamon-brown pustules which tend to coalesce. The petioles and the stems may also bear a few pustules, especially when the rust is very severe.

Fig. 1. Gram rust (*Uromyces ciceris-arietini*). Infected leaf $\times 2$. Uredia and telia with spores $\times 750$

Germination of the spores

Butler [1918] states that the urediospores remain capable of germination for at least a month but does not say whether he succeeded in germinating the teliospores. Considerable work has been done in these investigations to obtain the germination of both the spore forms and to see how long they remain viable.

Leaves of IP gram variety 17 containing both the uredia and the telia were collected in April 1938 at Karnal. The material was divided into four lots and stored under different conditions as follows :

(1) Leaves packed in cellophane packets which were then placed in stout manila envelopes and stored in a refrigerator at 6°C.

(2) Leaves placed in a dry glass tube which was then tightly corked and sealed with wax and placed in ice in the refrigerator.

(3) Leaves packed as in (1) and then buried in dry, sterilized soil in pots and these pots kept in the open.

(4) Leaves packed as in (1) and the envelopes stored in shade in the laboratory.

The urediospores and the teliospores were tested for their germination immediately before storing and the tests were repeated once a fortnight thereafter.

In order to standardize the method of germinating the spores, the following three tests were made : (1) germinating the spores in a drop of water placed on a slide and incubating them in a moist chamber ; (2) floating the spores on water in Syracuse watch glasses and then counting those that have germinated ; and (3) dusting the spores on moistened cellophane strips. The last named method gave uniformly good results and was adopted. For this purpose, the cellophane sheet was cut into strips two inches long and one inch broad and soaked in water for six hours. They were then jerked to remove excess water and placed flat on the slide. The spores were dusted on the strips with a brush and the slide then incubated in a moist chamber.

After having found the most suitable method of germinating the spores, attempts were directed towards finding a suitable medium in which to germinate them. The following liquids were tried and the results are recorded in Table I.

TABLE I

Per cent germination ofurediospores at 32°C. after 36 hours

Medium	Percentage
Distilled water	88
Tap water, pH=7·6	84
0·01 per cent malic acid	86
0·05 per cent malic acid	92
0·1 per cent malic acid	86

The spores germinated quite readily producing the germ tubes in two hours. The germ tubes followed a rather tortuous course, there being a single germ tube per spore in a majority of the cases. They attained a length of 200 to 400μ, after which the apical cell became markedly swollen and often lobed. The protoplasm got accumulated in the apical cell and one or two adjacent ones, while the rest of the tube was empty. As the per cent germination in distilled water was sufficiently high, it was alone used in subsequent trials.

The effect of temperature on freshly collected urediospores was then studied. The spores were mounted on cellophane strips soaked in water and the moist chambers were placed in incubators adjusted to different temperatures. The results obtained are recorded in Table II.

TABLE II

Effect of temperature on the germination of the urediospores

Temperature °C.	Per cent germination	Average length of germ tubes in μ
17	86·4	120·0
20	84·5	186·0
22	86·3	323·0
26	85·9	380·0
32	82·5	125·0
37	56·2	80·0

It will be noted from the data recorded in Table II that temperatures between 17° to 32°C. are very favourable for the germination of the spores though temperatures between 22° to 26°C. appear to favour more vigorous and better growth of the germ tubes. Above 32°C. germination declined rapidly.

VIABILITY OF THE UREDIOSPORES

Germination tests to see the viability of the urediospores stored under different conditions were conducted every fortnight commencing from 15 April, 1938. It was found that the spores from the material buried in the soil in pots and placed in the open lost their viability within two weeks. The spores from the material kept in the laboratory at room temperature of 30° to 40°C. showed only two per cent germination after two weeks and none after four weeks. The spores from the material kept in sealed glass test tubes and embedded in ice continued to germinate normally until the end of the fourteenth week when water accidentally got into the tube and the per cent germination thereafter became low and by the eighteenth week it entirely ceased. The material kept in the refrigerator chamber at 6°C. continued to germinate till the following December, that is up to 34 weeks. A gradual decline in germination became noticeable, however, after

the twentyfirst week onwards and the germ tubes showed a tendency to burst at the apex 36 hours after the spores started germination which was not shown by freshly collected spores. It will be manifest from these tests that urediospores stored under suitable conditions remain alive until long after the gram crop of the succeeding season has been sown (usually in early October). The results are shown in the following graph (Fig, 2)

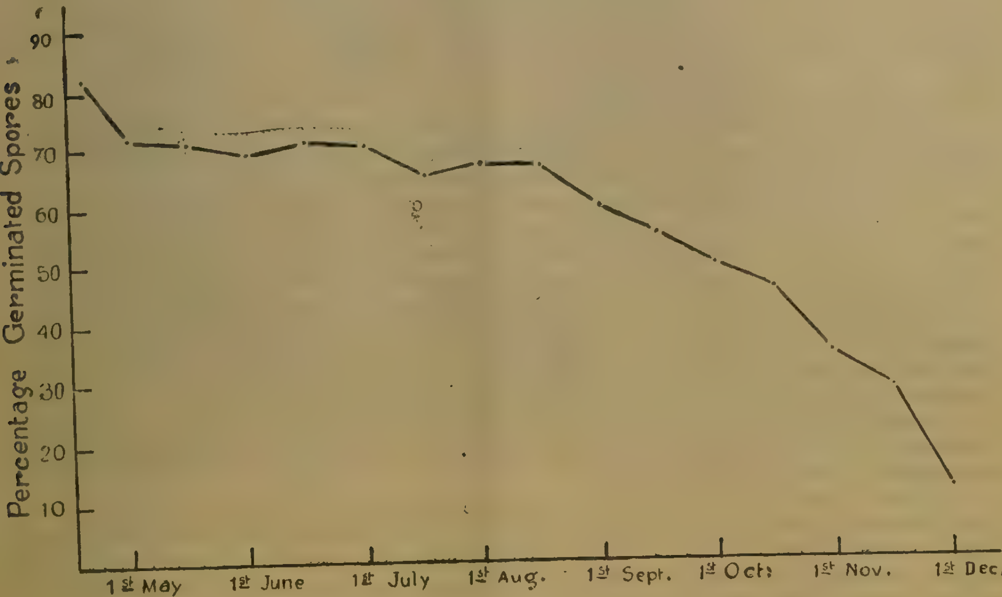

Fig. 2 Per cent germination of urediospores at different intervals of time

Germination of the teliospores

Several attempts were made to germinate the teliospores. Alternate chilling and thawing, effects of the vapours of alcohol, chloroform, different concentrations of ethylene chlorhydrin, effect of soaking the spores in water for different periods, etc. were tried. Teliospores collected early and late in the season and from sori from partially shaded plants were also given a trial. In all cases uniformly negative results were obtained. A more careful investigation is, however, necessary to elucidate the factors that induce the teliospores to germinate.

Infection experiments

Infection experiments were carried out in two ways. Clinton and McCormick [1924] reported a method of infecting detached but still living leaves of the host plant with rusts, which has been further elaborated by Waters [1928]. That method was used in the first set of experiments.

Tender shoots with a few leaves were detached from one month old plants and washed several times with sterile water. They were then placed in large petri dishes containing five per cent cane sugar solution and the urediospores were applied with a brush. These dishes were placed in incubators registering 8°C., 17°C., 20°C. and 24°C. temperatures respectively. The sugar solution was changed every third day but the shoots were exposed to strong light for half an hour daily. The results are recorded in Table III.

TABLE III

Effect of temperature on the incubation period of the uredial stage

Temperature °C.	Incubation period	Character of the sorus
8	27 days	Numerous, tiny
17	17 days	Numerous, tiny
20	13 days	Few, large
24	11 days	Few, large

The shoots kept in the incubator registering 24°C. turned yellow after two weeks. Some shoots were also kept at a temperature of 27°C. but the material could not be kept alive even for a week. Telia were not formed on any of the shoots in these experiments.

In a second set of experiments, the tests were carried out on plants growing in pots. The plants were about six weeks old. They were first sprayed with distilled water the previous evening and placed in a chamber over night. Early the next morning they were sprayed with suspensions of spores and the plants were placed in an incubation chamber for 24 hours, after which they were placed on the green house bench. Later in the evening, some pots were placed in chamber number one in the pot culture house where the temperature varied from 22°C. to 30°C., a second lot in chamber number two where the temperature varied from 20°C. to 27°C. and the last lot in chamber number three where the temperature varied from 17°C. to 24°C. The plants kept in chamber one developed chlorotic areas on the seventh day and the pustules erupted through the epidermis on the eighth day ; those kept in chamber two showed the chlorotic areas on the eighth day and the sori erupted on the ninth day ; those placed in chamber three showed the chlorotic areas on the eleventh day and the pustules erupted on the twelfth day.

In these experiments the urediospores used were those stored in cellophane packets and kept in the refrigerator under dry conditions at 6°C. It will be noted that the urediospores not only remain viable for over 34 weeks if stored under proper conditions but are even able to attack the host and bring about infection. The tests were carried out in November, 1938, at which time the urediospores were about 27 weeks old.

DEVELOPMENT OF THE TELIA

Plants of IP variety 17 were raised in small pots in November and the plants were infected after they were four, five, six, etc. up to sixteen weeks old using two pots for each test. The telial stage appeared towards the end of March irrespective of the time of infection or the age of the plants when they were infected. It is manifest therefore that the appearance of the telial stage depends on a complex of climatic factors that are prevalent about the end of March and not necessarily on the age of the plants when they are infected.

VARIETAL RESISTANCE

In order to determine the resistance of some gram varieties, plants were grown in small pots and infected when they were 16 days, 30 days and 45 days old. The same procedure for infecting the plants as before was followed. The pots were watered with a constant quantity of water every 36 hours. The following Imperial Pusa varieties of gram were tested : 2, 8, 9, 10, 12, 14, 17, 21, 30, 32, 43, 50, 53, 73, 78 and 82.

Due to the small size of gram leaves it was difficult to estimate the area of the leaf occupied by the sori using the method adopted by Fromme and Wingard [1921] for bean rust or the standard method in use in the United States Dept. of Agriculture for wheat rust. The following method was therefore adopted : the attacked leaves were carefully washed with water using a sprayer to remove the superficial spores which otherwise obscured the leaf area occupied by the sori. Numbers, 1, 2, 3 and 4 were then assigned to indicate the severity of infection, 1 indicating least infection and 4 the highest, for each plant as a whole.

The results thus obtained were checked by obtaining random samples of leaves, boiling them in alcohol to remove the chlorophyll so that the sori could be clearly seen and then counting the sori. In severe infections 74 sori were counted on a plant whereas in mild infection as few as eight were present. A key to the numbers to denote the severity of infection is given below :

1=Pustules very minute ; secondary sori nil ; epidermis slightly ruptured ; no chlorosis around the pustule ; leaves and rarely stipules affected.

2=Pustules medium sized ; secondary sori absent ; slight yellowing around the pustules, sometimes violet ; epidermis slightly ruptured ; leaves mainly affected, petioles only slightly.

3=Sori medium sized ; secondary sori few ; epidermis ruptured ; severe yellowing of younger leaves and production of violet colour in older ones ; leaves and petioles attacked.

4=Sori big ; secondary sori very common ; epidermis completely ruptured ; extensive chlorosis and yellowing of the leaves ; leaves, petioles and stems also attacked.

The data are presented in Table IV.

TABLE IV

Susceptibility of IP gram varieties to rust infection

Variety	Severity of infection		
	16 days old	30 days old	45 days old
2	4	4	4
8	1	3	3
9	2	2	3
10	3	4	4
12	1	4	4
14	4	3	4
17	3	3	3
21	2	3	2
30	4	4	3
32	3	2	2
43	1	3	3
50	3	2	2
52	1	2	2
53	4	3	4
63	2	3	3
78	1	2	2
82	3	1	2

From the data recorded in Table IV, it will be observed that some of the varieties do have a certain amount of seedling resistance which, however, gets broken in the adult stage. In one case, that of IP variety 82, the plants that were susceptible in the seedling stage, have shown some adult resistance. A certain amount of correlation between the age of the plants and their susceptibility to infection is indicated.

These experiments have shown that the method of infection and of taking the readings are satisfactory. The results are an indication of what can be achieved if large scale experiments are undertaken and that among the numerous varieties of gram there may be varieties that have resistance to attack by this rust, and that such investigations if undertaken may give fruitful results.

FIELD OBSERVATIONS

In April 1939, one of us (P.R.M.) proceeded to Karnal to take observations on the gram crop growing there and the extent of attack of the different varieties, of which sixty were under cultivation. The following observations were made :

Highly infected : IP 15, 22, 23, 24, 34 and 58

Moderately infected ; IP 1, 2, 3, 4, 12, 14, 16, 25, 26, 28, 44 and 48

Slightly infected : IP 29, 30, 31, 32, 33, 35 and 55

No rust on plants : IP 6, 10, 11, 13, 17, 18, 19, 20, 27, 36, 37, 38, 39, 40, 41, 42, 43, 45, 46, 47, 49, 51 52, 53, 54, 56, 57, 59 and 60

Discussion

The investigations reported in this paper have furnished one definite conclusion that it is possible to keep the urediospores viable for 34 weeks, and perhaps more, so that inoculum is available for experimental work in the succeeding season without having to wait for the appearance of the disease in nature. While resistance tests have not given conclusive results, indications are that there exist varieties of gram that are resistant to this rust. In these tests it was noted that not all the plants of a single variety showed the same intensity of attack indicating that so far as their reaction to the disease is concerned, they may be heterozygous. It should be possible to build up resistance in selections from such varieties. By including a larger number of varieties obtained from all over the country and abroad and concentrating attention on adult resistance, as the disease does not appear in the fields before the plants are 10 to 12 weeks old, it should be possible, we think, to obtain highly resistant varieties.

Success has not attended our efforts to germinate the teliospores and the matter may not be simple. Further work is necessary so that the capacity of the sporidia to infect gram plants or others has to be carefully explored. As the urediospores stored at laboratory temperatures or buried in the soil lose their viability within a month, there is little doubt that in nature they do not play any role in bringing about rust epidemics. As the disease does not appear before February, and answer to the question 'where it comes from' will give clues for devising other methods for its control.

Summary

The morphology of gram rust is given and the symptoms it produces are described. It has been shown that the urediospores germinate very well in 0·05 per cent malic acid solution and also in distilled water and that a temperature of 20°C. to 26°C. favoured both good germination and the best growth of the germ tubes. Urediospores stored at room temperature or buried it in the soil in pots left in the open lost their viability in two to four weeks but if stored at a cooler temperature, especially at 6°C., they kept viable for a long time.

Detached gram leaves floated on sugar solutions were readily rusted by the urediospores of the previous season stored at 6°C. and they were also able to infect gram plants growing in pots. The incubation period for the appearance of uredia was about 27 days at 8°C. but only 11 to 13 days at 20°C. to 24°C.

A number of gram varieties were tested to see their ability to resist the disease. Some showed seedling resistance which broke down as the plants grew older. One variety which was rather susceptible in the seedling stage was mildly attacked in a more adult stage, perhaps because it had adult resistance.

Teliospores could not be germinated and the pycnial and the aecial stages are still unknown. The implications of the observations made in these investigations are discussed.

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SEED TRANSMISSION OF STEM-ROT OF JUTE AND ITS CONTROL

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(With Plate XIX and one text-figure)

Varada Rajan and Patel [1943] have suggested that the infected jute seed is a more important source of primary infection of *Macrophomina phaseoli* (Maubl) Ashby than the soil. In some samples they found as much as 30 per cent infected seeds. The work reported herein furnishes evidence for transmission of the disease through the seed, measures for the elimination of seed-borne infection and some data on the role of seed and soil-borne infections.

Seed infection

Evidence for seed-borne infection. That the disease is transmitted through the seed was suspected when superficially sterilized seeds grown asceptically in tubes produced rots, hyphal growths, and lesions on unviable seeds, sprouted seeds and seedlings. The fungus isolated from these infections was *Macrophomina phaseoli*. When the seeds were washed in sterilized water and sown on sterilized soil, 25 per cent of the seedlings were found to be infected and the symptoms were typical of the disease as it occurs in the field. When the sterilized water in which the seeds were shaken was examined under the microscope small sclerotia were noticed. This suggested that the fungus is borne on the surface of the seed. Sclerotia and pycnidia are found on the outer surface of the entire seeds.

To ascertain whether the fungus harbours within the seed, seeds were superficially sterilized and plated on potato dextrose agar and incubated at 32°C. From data given in Table I it appears that the fungus is embedded within the seed. The difference in the percentages of infection may be due to the differences in the penetrating power of the chemicals.

Table I

Test for the seed-carriage of the fungus

Treatment for 20 minutes in	No. of seeds plated	Percentage infected
Formalin 1 per cent	1586	2·67
Mercuric chloride 0·01 per cent	1651	8·11
Sulphuric acid 5 per cent	1751	4·05
Hot-water (75°C.—80°C.)	1730	0·00
Untreated	1770	8·87

Macerated seeds when examined under a binocular microscope show sclerotia and mature hyphae under the seed coat, and sometimes in the cotyledon. Hand sections of discoloured seeds show numerous sclerotia and mature hyphae within the tissues (Plate XIX, figs. 1-3)

Mode of seed-infection. Repeated observations carried out over a number of seasons have shown that the various stages by which infection takes place are as follows.

The flower-bearing branches are commonly infected through the leaves of axillary branches. The rot spreads upwards and infects the capsules. Direct infection of the capsule through pycnospores

has also been noticed. The infection covers the capsule and enters within from the apex. The sclerotia occur on the placenta as well as in the locules, but they are denser at the distal end. At the proximal end the seeds remain free from infection. The fungus penetrates the seed tissues, possibly through the micropylar end.

Mature capsules on infection often split and shed the seeds. The immature capsules on infection dry up and drop off. In split capsules, exposed seeds have pycnidia. The extent of capsule infection varies from year to year depending upon the rains. Late rains cause extensive capsule infection. Early maturing types are usually caught in the rains and are badly infected. *C. capsularis* is infected more than *C. olitorius* or other wild species of *Corchorus*.

Technique for the detection of diseased seed. Several methods were tried out for estimating the percentage of infected seed, but that of plating 30 seeds on 10 c.c. of potato dextrose agar in petri dishes (100 mm. × 15 mm.) proved the handiest and the quickest. Plated seeds were incubated at 32°C. until the germination was complete and the colonies had grown to about one centimetre. Hyphal growths were visible on the seed within 24 hours and the sclerotia could be seen in the medium within three days. By this time distinct colonies were formed around contaminated seeds. In a plate all the infected seeds did not put forth fungal growths on the same day. This variation was attributed to the differences in the extent of infection and the depth at which the fungus was embedded. While only *Macrophomina phaseoli* was commonly obtained from such isolations, occasionally *Diplodia* sp., *Phomopsis* sp., *Fusarium* sp. and some general fungal and bacterial contaminants were isolated. The stem-rot fungus could be recognized by its characteristic upright hyphal growths from the seed and by the formation of small sclerotia. The disease percentage was calculated on the number of seeds sprouted or unsprouted which yielded *Macrophomina* fungus. It only took about a week to complete the pathological examination of a sample of seed.

In determining the percentage of total infected seeds it was necessary that the fungus on the surface of the seed was not destroyed. At the same time it was essential that all bacterial contamination was eliminated. Therefore, prior to plating, the seed was dipped in one per cent sterilized lactic acid.

On the other hand, when only the percentage of seeds with deep seated infection was to be estimated it was necessary to sterilize the surface of the seed. For this purpose 0·1 per cent mercuric chloride in 70 per cent alcohol was found suitable. The seeds could be steeped up to 20 minutes without any loss in viability. Alcohol assisted in eliminating air bubbles and in preventing lump formation. If necessary, seeds were kept under partial vacuum by working the suction pump. Before plating the seeds were washed in several changes of sterile water. For obtaining reliable and reproducible results, it was necessary to sample the seeds properly. A handful of seeds might be sub-divided uniformly till approximately 30 seeds were obtained. To determine whether the sampling method was reliable, from a common bulk, five lots of samples were drawn and replicated ten times. The differences in the disease percentages between the five lots did not prove significant. This standard technique was adopted for all the experiments.

It would have been ideal if in all the experiments only seeds from a common bulk were used. But as the magnitude of the work could not be foreseen, different bulks had to be used. In the experiments that are to follow wherever the change of seeds has occurred, it has been mentioned. In all the experiments seeds of *capsularis* strain D 154 were used.

Effect of seed-borne infection on germination. Healthy seeds appear smooth, glossy and brown in colour whereas the infected seeds have a dull surface, and are often a shrunken appearance.

A sample of seed was examined under a binocular microscope, and the seeds were classified into four groups, viz. (i) with sclerotia, (ii) with hyphal growths only, (iii) light and shrivelled, and (iv) healthy. They were plated on potato dextrose agar media and percentages of germination and disease were recorded. From the data given in Table II, it may be noted that of those that were classed as healthy, 5 per cent showed the disease. Nearly 8 per cent of seeds were light and shrivelled and of these only 25 per cent germinated. Those that had sclerotia or hyphal growths either did not germinate or produced only diseased seedlings.

TABLE II

Seed analysis

—	With sclerotia	With hyphal growths	Light and shrivelled	Healthy
Number	27	11	168	1934
Percentage	1·25	0·52	7·9	90·33
Germination percentage	0·0	16·0	25·0	93·7
Per cent of diseased seedling	0·0	100·0	12·1	5·5

From numerous experiments with plated seeds it is observed that healthy seeds record a higher germination than the diseased ones. Quite healthy seeds give 90 to 95 per cent germination. In ordinary samples more than 80 per cent of seeds are viable, but in severely infected samples the germination is very poor, 40 per cent of the seeds losing their viability owing to fungal attack, and 40 per cent showing disease on germination.

Badly infected seeds do not germinate and they are the first to put forth fungal growth. Slightly infected seeds give out only a few hypae at a later stage.

The fungus may come out from any part of the seed or the seedling. Simultaneously with sprouting, the fungus growths appear at the funicular end. Primary growths may also occur independently on the cotyledons, hypocotyl, collar and radicle. Under laboratory tests the primary infection invades the entire seedling which rots and produces pycnidia and sclerotia. Under green house and field conditions, the lesions in surviving seedlings often become localized and the seedling remains stunted.

ELIMINATION OF SEED-BORNE INFECTION

Gravitational methods. As diseased seeds are lighter than healthy ones, experiments were carried out, to investigate the possibility of separating the lighter diseased seeds by flotation with a liquid of such density that all diseased seeds would float while the healthy ones remained at the bottom. By adding suitable quantity of methylated spirit (0·8) to carbon tetrachloride (1·58) its specific gravity was reduced to 1·23, 1·13 and 1·09. The results are given in Table III, from which it is evident that the gravitational methods do not hold out any promise. Even when the specific gravity was as high as 1·23, more than 10 per cent of those which sank were diseased while over 36 per cent of the float ones were healthy.

TABLE III

Seed separation by gravitational method

Specific gravity	Mean percentage of		Mean per cent germination in		Mean per cent disease in	
	Floaters	Sinkers	Floaters	Sinkers	Floaters	Sinkers
1 (H_2O)	6·2	93·8	0·0	95·8	100·0	17·0
1·09	10·1	89·9	82·8	95·0	46·1	12·2
1·13	14·6	85·4	44·1	95·0	47·2	10·2
1·23	38·4	61·6	31·8	95·5	63·5	10·4

Heat. When seeds were heated in air they lost their viability considerably without lessening the seed infection. Even between 60°C. to 62°C., about 7 per cent of seeds showed the causal fungus. Hot water treatment of seed was, therefore, thought of. Seeds were soaked in water and air within

them was evacuated by using a suction pump, or by adding a few drops of 10 per cent castile soap both of which facilitated the sinking of seeds. After heating the tube containing the seeds, in a water-bath, it was transferred to cold water. To eliminate bacterial contamination the seeds were dipped in 1 per cent sterilized lactic acid prior to plating.

The results of four exploratory experiments (where the air was evacuated by means of a pump) are given in Table IV. Taking 80 per cent germination as satisfactory, it was found that treatments at 58°C. for 7 minutes, at 57°C. for 10 minutes, or at 56°C. for 20 minutes reduce seed infection from 22 to 1 per cent.

TABLE IV

Hot water treatment of seeds (air evacuated with a pump)

Range 0°C.	Duration in minutes	Experiment I		Experiment II		Experiment III		Experiment IV	
		G. P.	D. P.	G. P.	D. P.	G. P.	D. P.	G. P.	D. P.
55	10	86·4	5·5	..	..	..	..	..	..
55	20	89·6	4·3	89·7	3·6	..	..	..	..
55	25	..	..	81·2	1·9	91·3	1·9	..	..
55	30	91·0	3·2	65·6	0·7	87·8	1·9	..	..
55	40	78·9	1·4	..	..	68·5	0·4	..	..
56	10	88·8	3·7	92·2	6·2	..	..	75·9	1·5
56	15	..	..	83·0	2·4	..	..	76·9	1·1
56	17	..	..	..	..	84·3	4·9	79·2	0·0
56	20	84·1	3·5	79·1	1·1	..	..	80·5	0·0
56	30	69·8	1·0	..	..	..	..	..	..
56	40	46·4	0·0	..	..	..	..	..	..
57	10	93·8	4·3	81·0	2·1	83·4	4·9	89·1	0·7
57	15	..	..	84·6	1·1	..	..	78·4	0·4
57	17	..	..	..	..	..	..	78·1	1·1
57	20	83·4	1·4	63·7	0·3	..	..	65·9	0·4
57	30	63·5	0·4	..	..	..	..	..	..
57	40	28·2	..	..	..	..	..	..	..
58	5	..	..	87·0	4·0	..	..	..	..
58	7	..	..	..	..	82·1	3·7	80·8	1·1
58	10	..	..	54·6	0·0	..	..	..	..
Control . .	..	89·4	23·7	91·5	22·9	95·1	25·1	94·6	22·7
Critical difference	..	12·3	3·2	10·7	3·8	11·2	4·3	9·4	2·6

G. P.=Germination percentage ; D. P.=Disease percentage

In the second set of four experiments where castile soap was used, treatments at 57°C. for 25 minutes, at 58°C. and 59°C. for 15 minutes were quite effective in reducing the disease without affecting the germination (Table V).

TABLE V

Hot water treatment (Evacuation with castile soap solution)

Duration in minutes	10		15		20		25	
Range 0°C.	G. P.	D. P.	G. P.	D. P.	G. P.	D. P.	G. P.	D. P.
57	93·8	7·8	81·7	8·1	76·1	10·8	84·9	2·9
58	88·3	6·1	81·2	4·5	59·6	5·3	49·9	3·9
59	82·4	6·9	87·3	4·1	46·5	3·4	68·0	2·7
60	78·2	9·4	64·8	2·6	64·7	2·4	35·5	0·0
Untreated . . .	92·5	22·1	96·0	25·0	93·2	18·0	95·0	20·5
Critical difference . .	9·3	4·8	14·5	5·3	24·5	6·2	16·7	5·8

G. P.=Germination percentage ; D. P.=Disease percentage

Since the sclerotia are associated with the mature hyphae in the seed, it was thought that pre-soaking might activate the hibernating fungus and the following hot-water treatment may prove more effective. The seeds were soaked in water from one to four hours at room temperature which averaged at 28°C. during the course of the experiment. The pre-soaked seeds were subjected for 15 minutes to treatments from 48°C. to 62°C. at one degree intervals, and after cooling were plated. From 48°C. to 55°C. the same sample of seed was used, but from 56°C. onwards another sample which was more infected had to be used. Since for each treatment there were five replications, the data for each temperature treatment was analysed separately by analysis of variance.

From the data in Table VI it may be seen that, excepting at '48°C. one hour pre-soaking', in all the remaining 59 treatments pre-soaking followed by hot water treatment lessened the disease significantly, but the reduction was considerable only at 61°C. and 62°C.; where the germination fell to 55 per cent. Only in four temperature treatments out of 15, the differences between the durations of pre-soaking were significant in respect of the disease. Pre-soaking for one hour seems to be almost as good as pre-soaking for four hours. Up to 58°C. there was no appreciable effect of durations of pre-soaking and of heat-treatment on germination. From 59°C. to 62°C., in general, higher temperature and longer pre-soaking up to three hours, reduced the germination. At this range the differences between three and four hours pre-soakings were negligible.

Table VI

Effect of pre-soaking and hot water treatment

Pre-soaking (a)	One hour		Two hours		Three hours		Four hours		Untreated		Critical difference	
Range 0°C.	G. P.	D. P.	G. P.	D. P.	G. P.	D. P.	G. P.	D. P.	G. P.	D. P.	G. P.	D. P.
48	88·2	13·9	90·8	9·7	91·9	9·1	90·1	9·6	87·4	14·9	Not significant	4·7
49	69·0	10·4	73·3	10·2	75·4	9·6	81·0	10·8	71·9	17·3	,,	4·8
50	88·0	12·9	87·6	15·1	88·7	10·8	83·9	9·1	86·4	23·1	,,	5·7
51	83·1	10·5	82·6	8·2	85·6	7·6	76·4	6·4	84·5	16·8	,,	5·1
52	79·4	11·6	79·0	10·0	79·8	9·5	80·3	9·5	82·3	21·0	,,	5·2
53	85·8	8·2	83·2	10·1	84·6	5·1	82·9	5·5	91·5	17·8	,,	7·4
54	88·2	10·3	88·8	8·4	88·9	8·3	90·1	9·9	90·6	17·3	,,	5·1
55	91·3	9·6	84·6	7·6	86·9	7·8	82·0	7·1	83·6	14·3	,,	3·9
56*	87·3	15·5	79·6	6·7	86·6	11·4	79·3	12·4	88·5	35·4	5·6	5·3
57	81·9	10·6	84·2	11·7	80·9	10·8	78·0	11·6	81·3	32·1	Not significant	3·6
58	85·8	14·5	82·3	11·9	75·2	14·5	75·7	15·3	79·9	33·7	,,	6·0
59	76·8	9·5	62·5	12·4	61·4	8·1	59·6	11·8	83·3	31·5	10·9	6·1
60	91·3	10·6	80·3	8·1	68·3	9·1	60·0	5·0	84·6	27·3	6·9	5·2
61	53·7	3·0	48·7	2·4	27·4	1·8	21·2	0·3	92·5	29·5	9·1	4·0
62	58·0	4·3	37·0	2·4	15·9	1·3	17·8	2·4	90·1	31·9	12·7	3·1

(a) = mean of 5 sets; G.P.=Germination percentage; D.P.=Disease percentage

*Sample of seed was changed at 56°C.

To locate a safe temperature range for the treatment, lethal temperatures for the seed, for the fungus in the seeds and for the sclerotial suspension were worked out by steeping these materials in hot-water ranging from 30°C. to 55°C. at intervals of 5°C., and thereafter at 1°C. interval till 70°C. The duration of the treatment was 15 minutes throughout. The data have been illustrated in Fig. 1. The viability of seeds was fairly steady till 57°C., thereafter it fell gradually till 63°C. when an abrupt fall occurred. In the fungal out-growths from the seed, there was a gradual decline from 45°C. to 54°C., and from 55°C. to 60°C. there was a steep fall. The zone for effective treatment appears to be between 55°C. and 60°C. Even at 70°C., 0·3 per cent of the seeds retained viable fungus. Since

temperatures above 56°C. proved lethal to pure sclerotial suspension, it seems that deep location within the seed helps the sclerotia in surviving higher range of temperature.

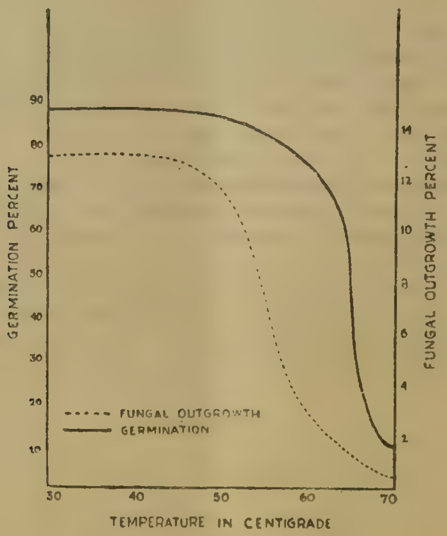

FIG. 1.

Chemicals. Seeds were treated in cold and hot solutions of formalin, mercuric chloride and copper sulphate for 15 or 20 minutes. Prior to treatment the air bubbles were forced out either under suction pump or by addition of 10 per cent castile soap. Four to five replications were given and the results obtained from plated seeds were analysed by analysis of variance (Table VII).

TABLE VII

Treatment of seed by liquid disinfectants

Treatment	Strength in percentage	Range in 0°C.	Duration in minutes	Mean G. P.	Mean D. P.	Remarks
Formalin	2	Cold	20	91·6	6·3	
	3	,,	20	89·5	7·4	
	4	,,	20	91·2	8·8	
	5	,,	20	91·0	4·6	
	6	,,	20	92·2	6·8	
Untreated	..	..	..	91·8	13·3	
Critical difference	..	..	..	Insignificant	5·0	
Formalin	2	52	20	62·1	1·7	Air evacuated from the chemical for the duration
	2	55	20	18·7	1·0	
	2	56	20	28·3	0·4	
	2	57	20	22·4	0·9	
	2	57	20	72·3	2·7	Air evacuated from water and chemical introduced
	2	60	20	37·0	2·7	

TABLE VII—*contd.*

Treatment of seed by liquid disinfectants—contd.

Treatment	Strength in percentage	Range in 0°C.	Duration in minutes	Mean G. P.	Mean D. P.	Remarks
Untreated	..	..	..	95·2	16·6	
Critical difference	..	..	..	14·6	2·9	
Formalin	1·5	55	15	49·8	9·8	Change of seed
	1·0	55	15	46·7	8·1	
	0·5	55	15	83·6	13·3	
Untreated	..	..	..	93·2	32·1	
Critical difference	..	..	..	7·7	8·1	
Mercuric chloride	0·1	48	20	71·5	12·4	
	0·1	50	20	67·7	11·2	
	0·1	52	20	81·7	11·3	
	0·1	54	20	73·8	4·1	
	0·1	56	20	72·4	3·4	
	0·1	58	20	33·4	1·0	
	0·1	60	20	24·1	0·5	
Untreated	..	..	..	93·0	24·1	
Critical difference	..	..	..	12·1	1·4	
Mercuric chloride	0·1	55	15	84·8	12·0	
	0·2	55	15	87·8	11·0	
	0·4	55	15	26·2	0·0	
	1·0	55	15	3·2	0·0	
	1·5	55	15	3·1	0·0	
Untreated	..	..	..	90·3	26·1	
Critical difference	..	..	..	6·0	3·4	
Copper sulphate	2	Cold	15	81·0	27·2	Change of seed
	5	„	15	81·2	28·0	
	10	„	15	87·9	26·3	
	15	„	15	86·1	33·4	
Untreated	..	..	..	87·1	34·0	
Critical difference	..	..	..	Not significant		
No copper sulphate	..	55	15	91·1	11·7	
Copper sulphate	2	55	15	93·8	18·5	
	5	55	15	91·4	8·0	
	10	55	15	92·5	10·8	
	15	55	15	90·1	9·4	
Untreated	..	..	..	91·2	27·2	
Critical difference	..	..	..	Not significant	4·96	

G. P.=Germination percentage; D. P.=Disease percentage

That cold mercuric chloride has practically no effect on the seed fungus may be seen from Table VIII. Mercuric chloride when applied for 20 minutes at 54°C. or 56°C. reduces the infection, but also lowers the germination to 70 per cent (Table VII). Cold copper sulphate solution has no effect and, when applied hot, did not check the disease sufficiently. Hot formalin was quite effective in controlling the disease but lowered the viability of seeds. Of the three sterilants tried formalin, cold or warm, was the best.

The disadvantages of treatments with liquids are well known. Dusts are much more convenient to work with. Dusts of sulphur, naphthalene, copper carbonate and proprietory seed dressings like Ceresan, Nomersan and Agrosan G were compared with hot water treatments. In experiments I and II in Table VIII, the method used for dusting the seeds was defective and was modified in experiments III and IV, in which seeds were shaken with the dust for two minutes and the excess of dust removed by sieving. The first three experiments were conducted on potato-dextrose agar plates but the last one was carried out on sterilized sand in petri-dishes.

TABLE VIII

Comparative efficiency of various treatments

Treatments	Experiment I		Experiment II		Experiment III		Experiment IV	
	G. P.	D. P.	G. P.	D. P.	G. P.	D. P.	G. P.	D. P.
Mercuric chloride 0·1 per cent (cold)	88·5	23·2	92·0	18·6	..	..	..	..
Formalin 5 per cent (cold)	91·8	17·4	80·7	15·7	..	..	..	..
Copper carbonate	93·8	23·1	90·2	20·2	..	..	..	..
Sulphur	..	..	..	..	96·0	21·2	..	..
Lime	..	..	..	..	92·5	22·5	..	..
Napthalene	..	..	..	..	88·7	13·3	..	..
56°C. for 15 minutes	..	..	..	..	..	..	91·0	6·5
57°C. for 15 minutes	..	..	..	..	..	..	81·6	6·5
58°C. for 15 minutes	..	..	..	..	..	..	86·4	8·0
Ceresan	83·2	3·1	68·9	3·1	89·3	0·6	92·0	1·0
Agrosan G	93·3	10·3	92·0	15·5	94·7	5·8	91·8	2·9
Nomersan	93·2	11·8	86·7	17·8	92·4	1·0	94·5	1·5
Untreated	91·9	24·2	90·3	21·8	96·7	22·8	88·6	16·9
Critical difference	6·3	8·0	8·2	5·6	3·2	2·7	7·4	3·8

Experiments I, II and III conducted on potato dextrose agar, experiment IV on sterilized sand in plates. G. P.= Germination percentage; D. P.= Disease percentage.

Dusts of sulphur, lime, nephthalene and copper carbonate are not found efficient. Treatments with Ceresan, Nomersan and Agrosan G were quite effective and significantly better than hot-water treatments. These dusts when properly used did not hamper the viability of the seed.

These tests were extended to the field where in every season seedling mortality is a common feature. Counts of stand and seedling mortality were taken three weeks after sowing. The experiment was repeated on the same plots and data recorded, as per Table IX. As the differences in the stand were not significant, it suggests that the treatments did not have any phytocidal effect. Treatments with dusts and hot-water and the use of disease-free seed proved effective in checking the seedling mortality.

TABLE IX

Effect of seed treatment on mortality in field

Treatments	Experiment I		Experiment II	
	Stand	Mean disease per cent	Stand	Mean disease per cent
56°C. for 15 minutes	404	0·0	326	1·1
57°C. for 15 minutes	384	0·2	344	0·7
58°C. for 15 minutes	381	0·2	366	1·0
Ceresan	453	0·4	391	0·8
Nomersan	434	0·1	306	1·5
Agrosan G	403	1·2	373	0·8
Disease free seeds (untreated)	464	0·2	340	1·7
Control untreated	425	5·2	307	8·1
Critical difference	Not significant	1·07	Not significant	1·29

Layout—Randomized in six replications

Effective size of plot 3 ft. × 6 ft. Experiment I, sown on 2.5.42, Experiment II, sown on 26.6.42

In Table IX the disease in untreated control is rather low. In order to see whether the treatment of highly infected seed is more beneficial, a badly contaminated sample was compared with a

healthy lot of seed. Both the lots of seed were treated with Ceresan and planted in sterilized sand and incubated at 32°C. The data in Table X establish the usefulness of treating badly contaminated seed.

TABLE X

Seed treatment in relation to quality of seed

Quality of seed	*Mean G. P.		Mean D. P.	
	Untreated	Treated	Untreated	Treated
Diseased	59·8	61·2	75·4	5·5
Clean	94·3	83·2	2·9	0·0

*Mean of 12 sets each containing approximately 30 seeds.

Christensen and Stakman [1935] have similarly reported that the value of treating barley seeds against *Fusarium* and *Helminthosporium* depended upon the degree of seed infection. Obviously there is no use of treating clean seed.

Seed disinfection in relation to soil. It may be asked that since the fungus can be in the soil, what is the use of seed disinfection. To bring out the contrast between disease free and heavily infected soils, seeds treated with Agrosan G, Ceresan and Nomersan were grown in pots on sterilized and inoculated soils under green house conditions. There were ten replications. From the data in Table XI it may be concluded that both on inoculated and sterilized soils, the germination of seeds treated with Ceresan and Nomersan was significantly superior to that of untreated and Agrosan G treated seeds. The germination on the inoculated soil was generally lower but significantly so only in the case of untreated seeds. On sterilized soil the disease was significantly less in the case of treated seeds. On inoculated soil the disease was very high ranging from 93·0 to 95·8 and there was no difference between the treated seeds and the untreated ones.

TABLE XI

Seed disinfection in relation to soil

Condition of seed	Condition of soil	Treatment	Mean percentage of	
			Germination	Disease incidence
Diseased	Sterilized	Agrosan G	76·8	11·9
		Ceresan	87·7	2·3
		Nomersan	86·0	7·7
		Untreated	74·3	18·8
	Inoculated	Agrosan G	70·0	95·8
		Ceresan	80·0	93·0
		Nomersan	78·7	94·2
		Untreated	63·3	95·4
	Critical difference		8·6	4·3

In the next experiment, field soil which is known to be infested with stem-rot was included along with sterilized and inoculated soil. Diseased and healthy seeds were used. Three hundred seeds were sown under each treatment and the pots were kept in a green-house. With a view to study the mode of initiation of the disease, the seedlings on which symptoms had just appeared were carefully uprooted and the seat of infection was located. The results are recorded in Table XII. On inoculated soil the disease is mostly initiated at the junction of the collar. While collar and radicle roots are associated with the soil infection, rots of cotyledon, hypocotyl, collar and radicle are associated with seed infection, but the aerial symptoms are predominant. On the field soil the use of disease-free seeds reduced the disease by nearly half, from 27·9 to 14·7 per cent. On sterilized soil, the use of diseased seeds yielded 16·3 per cent infection whereas with healthy seeds there was no disease. In this experiment the infection from the soil equalled that from the seeds and the seed infection had additive effect on the soil infection.

Table XII

Differences in seat of infection produced by the infected seed and soil

Condition of seed	Condition of soil	Discolouration at										
		Healthy	Cotyledon and seed-coat	Cotyledon	Hypo-cotyl	Junction (collar)	Radicle	Collar and radicle	Cotyledon and collar	Hypo-cotyl and collar	Percentage emerged	Percentage infection
Healthy	Sterilized (1)	252	..	..	..	..	..	..	..	..	84·0	0·0
	Inoculated (2)	6	..	..	..	200	28	24	..	..	86·0	97·6
	Field (3)	231	..	..	..	32	3	5	..	..	90·3	14·7
Diseased	Sterilized	154	5	6	8	5	2	..	2	2	61·3	16·3
	Inoculated	0	12	22	21	102	11	10	1	6	61·7	100·0
	Field	147	1	7	14	21	11	0	1	2	68·0	27·9

(1) Soil sterilized at 30 lb. pressure for one hour
(2) Soil inoculated with pure culture of *Macrophomina phaseoli* grown on jute seed sand media
(3) Field soil known to be infested with stem-rot fungus

Action of seed disinfectants. In experiments with dusts it was observed that on diseased dusted seeds hyphal growth was feeble despite the presence of sclerotia and mature hyphae within. This suggested the possibility of dusts inhibiting and retarding the fungal growth. With a view to test the action of the disinfectants on the disease, seeds treated in 0·1 per cent mercuric chloride for 10 minutes, Ceresan, Nomersan and Agrosan G were sown in sterilized test tubes on moist cotton wool. These conditions, i.e. high humidity and high temperature (28°C. to 30°C.), were favourable to the expression of the disease. Observations were made daily and seed rots, seedling rots and lesions on seedlings were recorded up to 10 days after sowing. In each treatment there were 400 seeds. From Part I of Table XIII it may be seen that Ceresan, Nomersan and Agrosan G were equally effective in controlling seed rots before the emergence of the seedlings. In preventing seedling rots, however, Ceresan and Nomersan were more effective than Agrosan G. Nearly half the seedling rots were due to the persisting contact of seed coat with the seedling. In untreated seeds the maximum of the seed rot is reached in two days after sowing whereas in dusted seeds this stage is not reached till six or seven days after sowing, vide part II of Table XIII. When the seeds were treated with Ceresan or Nomersan seedling rots hardly appeared till the fourth or the fifth day after sowing. This gave the seedlings a chance to establish.

TABLE XIII

Action of seed disinfectants

Part I

Treatment	Unviable No.	Pre-emergence mortality (seed rots per cent)	Per cent emerged	Post-emergence mortality (seedling rots): Infection per cent due to seed coat adherence	Infection per cent not due to seed-coat adherence	Total percentage
Untreated	13	16·7	80·0	32·2	30·0	62·2
Mercuric chloride 0·1 per cent	10	11·0	86·5	22·5	18·5	41·0
Agrosan G	15	4·5	91·7	10·3	11·5	21·8
Nomersan	11	5·2	92·0	2·4	4·7	7·1
Ceresan	11	4·7	92·5	2·4	3·2	5·6

Part II

Percentages of pre-emergence and post-emergence rots at days after sowing

No. of days after sowing	Untreated: Pre-emergence	Untreated: Post-emergence	Mercuric chloride: Pre-emergence	Mercuric chloride: Post-emergence	Agrosan G: Pre-emergence	Agrosan G: Post-emergence	Nomersan: Pre-emergence	Nomersan: Post-emergence	Ceresan: Pre-emergence	Ceresan: Post-emergence
1	14·0	0·6	9·5	0·0	0·5	0·3	0·0	0·3	0·2	0·0
2	16·1	3·1	10·5	1·8	1·7	0·8	1·0	0·2	1·2	0·0
3	16·7	15·0	10·5	10·7	2·5	2·4	2·0	0·5	1·5	0·0
4	16·7	22·2	10·5	15·0	2·7	6·2	2·7	1·3	2·7	0·8
5	16·7	29·1	10·5	20·2	3·2	9·8	4·2	2·6	3·5	1·3
6	16·7	44·1	10·5	27·4	4·0	12·5	4·7	3·5	4·0	1·9
7	16·7	55·3	11·0	31·2	4·5	16·1	5·0	4·6	4·2	2·7
8	16·7	60·3	11·0	36·7	4·5	16·8	5·2	6·1	4·7	3·2
9	16·7	62·2	11·0	40·7	4·5	17·9	5·2	6·2	4·7	4·3
10	16·7	62·2	11·0	41·0	4·5	21·8	5·2	7·1	4·7	5·6

The untreated seeds and seeds treated with mercuric chloride had profuse hyphal growths. The seeds treated with Agrosan G exhibited slightly more of fungal growth than those treated with Ceresan and Nomersan. The three dusts in general yielded very feeble growths. In some cases, though the detached seed coats yielded fungal growths, the seedlings remained healthy. The low infection in Ceresan and Nomersan treated seeds may be due to their inhibiting action on the growth of the fungus directly under the seed coat.

DISCUSSION AND CONCLUSIONS.

Varada Rajan and Patel [1943] have shown that pycnospores released from diseased and infected seedlings cause secondary infection which is usually four times the primary one. Measures that can reduce the primary infection have therefore special importance. Three factors affect the primary infection, viz. (i) extent of seed infection, (ii) extent of soil infection, and (iii) the conditions under which the infection expresses itself and develops.

Taking the last factor first, it is found that little is known of the conditions under which the fungus expresses itself and develops in the field. Field observations on seedling mortality carried out at Dacca during 1939 to 1943 show that wet sowing seasons favour seedling mortality, particularly when contaminated seeds are used. During such seasons, primary lesions appear on all the serial

parts and collar, but the roots mostly remain healthy. The radicles on isolation do not yield any fungus though the soil is known to be infected. In dry seasons collar and root rots are frequent, but after a time the discolouration shreds and the seedlings recover. The mortality is therefore low in dry seasons.

In 1942 at the Dacca Farm, there was a long spell of dry weather accompanied by high temperatures. During this period seeds having about 30 per cent infection were sown in 18 in. pots containing infected field soil. They were kept in the open, but in one set high humidity was provided soon after sowing, in the second set after the germination was complete and in the third a fortnight after sowing. The control pots were exposed to the prevailing dry atmosphere. In each of the four treatments 400 seeds were sown. As soon as the symptoms appeared, each of the infected seedling was uprooted and the initial place of infection recorded. Chances for secondary infection were thus minimized.

TABLE XIV

Effect of humidity on disease expression

Conditions	Primary infection						
	Percentage emergence	Cotyledon	Hypocotyl	Root or collar	Exact position not clear but root healthy	Total No. infected	Percentage of infection
Pots exposed to atmospheric condition	89·7	3	5	12	3	23	6·0
Pots kept under high humidity after sowing	91·7	26	12	12	32	82	22·3
Pots kept under high humidity after complete germination	90·5	21	16	15	47	99	27·6
Pots kept under high humidity a fortnight after sowing—							
(*a*) before covering . . .	92·7	3	4	11	..	18	4·8
(*b*) after covering . . .	..	8	13	18	27	66	17·8

From the data in Table XIV it is apparent that high humidity quadrupled the primary infection. Under field conditions, the effect of humidity on infection will be much more pronounced as rotting seedlings will lie in the field and will produce abundant pycnospores. It is pertinent that excessive humidity increased aerial symptoms much more than the collar and root rots. This suggests that the fungus associated with the seed has played, under the conditions of the experiment, a more important role in the initiation of the disease than that associated with the soil. Andrus [1938] has found that any condition that favours the adherence of the infected seed coat to the seedling will favour infection. Observations have shown that excessive humidity favours the adherance of the seed coat.

It is not the intention to say that on all soils, infected seeds play the most important role in the initiation of the disease. When the soil is artificially inoculated, it is invariably found that the disease is much more than on sterilized soil with the infected seed. Results of six experiments tabulated below (Table XV) bear this out, but on infected field soils with which we have worked, the disease is not as high as in the inoculated soil. If the infection from the soil is really heavy, the health of the seeds should not affect the percentage of disease incidence. That this is not the case is borne out by three facts. Firstly, when healthy seeds are sown on infected field soil, the disease is consistently less than when diseased seeds are used. Secondly, comparing the performance of contaminated seeds on infected and sterilized soils, it is found that the disease on the former is not very much more than on the latter. Thirdly, when diseased seeds on sterilized soils are compared with the healthy seeds on the infected soil, it is observed that the former show more disease than the latter.

TABLE XV

Soil versus seed infection

Kinds of seed used	Percent of disease incidence in plants grown on various kinds of soils		
	Sterilized	Inoculated	Infected field soil
Diseased	18·8	95·4	..
Diseased	25·3	68·1	..
Healthy	2·3	39·1	..
Diseased	50·2	79·9	51·1
Healthy	2·1	71·4	31·3
Diseased	16·3	100·0	27·9
Healthy	0·0	97·6	14·7
Diseased	39·3	83·2	43·9
Healthy	0·0	73·2	14·5
Diseased	30·5	87·0	41·2
Healthy	1·3	94·6	29·2

Surveys have shown that crop stubbles showing viable sclerotia occur rarely in lands that are inundated, sporadically in midlands, and considerably in high lands. The infected soil used in these experiments was from high lands of the Dacca Farm where the disease appears every year in considerable proportion. The authors have only once come across the disease in a more intense form than that at the Dacca Farm, and that was in mid-lands near Narsingdi. On low lands where the soil infection is negligible, considerable seedling mortality has been observed and this has been linked up with the use of infected seeds. At the sub-station at Konda, which is inundated every year, it is a common experience to find heavy seedling mortality in plots raised from Dacca seeds, whereas plots from locally collected seeds are practically disease free.

Amongst the methods tried for the disinfection of seeds, hot water treatment and seed-dressing proved effective. The latter is simple and is capable of wider use. Of the three dusts, Ceresan has consistently given better results, Nomersan being a close second. Agrosan G is clearly not as effective as Ceresan and is inferior to Nomersan. To facilitate comparison the relative performance of these three fungicides has been compiled in Table XVI. It is suggested that superiority of Ceresan and Nomersan over Agrosan G is due to their preventive action on post-emergence mortality.

TABLE XVI

Relative efficiency of seed dressings

Seeds grown on	Percentage of disease in seeds treated with			
	Ceresan	Nomersan	Agrosan G	Control
Potato dextrose agar in plates	0·6	1·0	5·8	22·8
On cotton wool in sterilized tubes	5·6	7·1	21·8	62·2
On sterilized sand in plates	1·0	1·5	2·9	16·9
On sterilized sand in plates	5·5	..	..	75·4
On sterilized soil in pots	2·3	7·7	11·9	18·8
Soil in fields	0·4	0·1	1·2	5·2
Soil in fields	0·8	1·5	0·8	8·1

Summary

Transmission of the stem rot disease of jute through the seeds has been demonstrated. Mature hyphae and sclerotia of the fungus *Macrophomina* are borne on and within the seed. The mode of infection of seeds and the technique for its detection have been described. This contamination of the seeds lessens germination and initiates primary infection. It is suggested that under ordinary conditions the role of the seeds in the initiation of the disease is more important than that of the soil. In heavily infected soils the use of disease-free seeds is of no avail in combating the disease, but such soils are rare. High humidity favours the development of the disease on seedlings as well as on seed-capsules.

For destroying the pathogen without affecting the viability appreciably, heating the seeds in water proved more useful than heating them in air. The zone for effective treatment appears to be between 55°C. and 60°C. Sclerotia that are located deep in the seed may survive even at 70°C. In activating the hibernating fungus, pre-soaking of seeds did not assist much.

Amongst the various chemicals tried, Ceresan, Nomersan and Agrosan G proved effective as seed disinfectants. Ceresan and Nomersan appear to be superior to Agrosan G. All the three can control seed rot, but Agrosan G is not as effective as the other two in preventing seedling rot.

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STUDIES ON THE VIRUS DISEASES OF POTATOES IN INDIA

III. OCCURRENCE OF SOLANUM VIRUS 3. MURPHY AND M'KAY

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(With Plate XX)

During the course of observations on the incidence of virus diseases of potatoes in the mycological area of this Institute, *Solanum Virus* 3 (Potato Virus A) was recovered from potato plants of *Phulwa* variety showing yellowing of the leaf margins or deep yellow brilliant mottle. The virus was also recovered from potato plants of variety *Darjeeling Red Round* which showed crinkling of leaves. The types of symptoms exhibited by plants from which the virus was recovered are described below.

Type 1. In *Phulwa* variety yellowing of the margins of the leaves was uncommon and only one plant showing such symptoms was observed in the whole area. When first observed the tips or the margins of some of the young leaflets exhibited yellow colouration. With age the yellowing became more pronounced covering larger portions of the margin and its progress inwards was limited by the minor veins while the dark green colour persisted in the central region. Some of the leaflets however, turned completely yellow. About two months later small circular necrotic spots appeared and gradually their number increased (Plate XX, fig. 1).

Type 2. The plants of *Phulwa* variety which exhibited yellow spots were different in that the young shoots on their emergence did not show yellow spots but after several weeks growth small yellow areas were observed on the old as well as the young leaves. The areas were irregular in shape and quickly assumed characteristic deep yellow colour. Frequently such areas merged to form

FIG. 1. A. Mycelium ; B. Sclerotial bodies (×60)
A transverse section of Jute seed (D154)

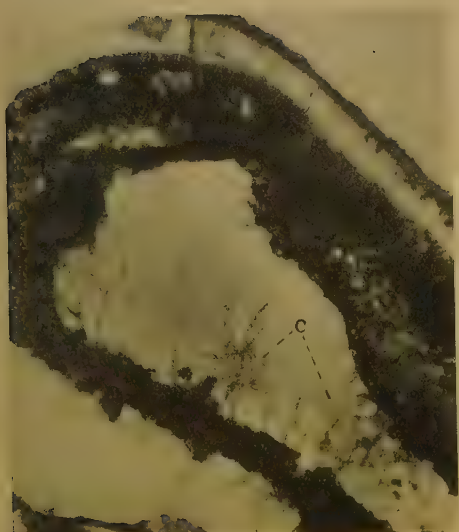

FIG. 2. C. Mycelium within the cotyledons (×300)

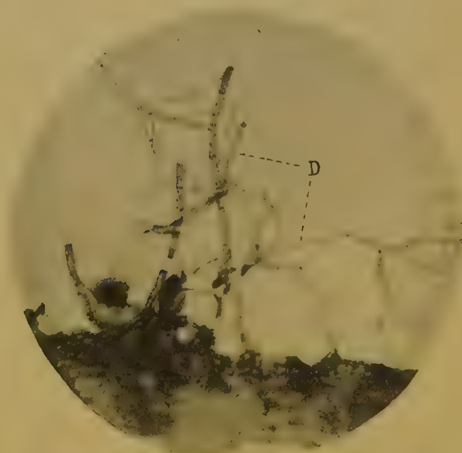

FIG. 3. D. Hyphal growths (×500)

Figs. 1 and 2. Leaflets of potato plants of *Phulwa* variety showing yellowing of the margins and yellow spots respectively
Fig. 3. *Nicotiana tabacum* showing green vein-banding
Fig. 4. *Nicotiana glutinosa* showing thickening of veins
Fig. 5. *Datura stramonium* showing yellow mottle after grafting with infected potato plant

larger areas. The yellowing was not accompanied by any other symptom except slight puckering occasionally. The plants raised from tubers of such plants for the last two years exhibited similar symptoms (Plate XX, fig. 2).

Type 3. In another lot of *Phulwa* plants small bright yellow circular or oval mottle was observed on the lower leaves of very young plants. As the plants advanced in age no additional spots appeared.

Type 4. The virus was also recovered from *Darjeeling Red Round* plants showing stunting and extreme puckering with downward curving of leaves. Diffused pale areas occurred all over the surface of the leaves. The colour of the foliage in general was pale green and the leaflets were brittle and could easily be damaged and detached from the plant.

Preliminary testing for host range was limited to a number of plants of the Solanaceae which are usually used for the identification of viruses. For these tests inoculations with standard extracts of *Phulwa* potato plants showing three types of symptoms and from *Darjeeling Red Round* plant showing crinkle were carried out. Wherever necessary grafts on some of the solanaceous plants and potato varieties were made by the cleft method.

The standard extract for inoculation purposes was prepared by crushing to a fine pulp in pestle and mortar a known weight of young infected leaves which had previously been washed and dried in folds of filter paper adding a small quantity of sterile distilled water at a time. To every gram of leafy material 1 c.c. of water was added. This material was then pressed through fine muslin by hand.

Inoculations were carried out by dusting the leaves, held in position over a piece of cardboard, with finely powdered carborundum and smearing the leaf with a piece of absorbent cotton wool dipped in fresh standard extract from the diseased plant. Controls were always maintained side by side. Every precaution was taken to maintain aseptic conditions and all the apparatus used was sterilized as considered necessary for each experiment.

All the experimental work was carried out in an insect proof house and transmission tests were conducted both by mechanical means and by grafts as required in individual cases. In order to provide a stock of freshly infected plants for inoculation work the culture of the virus was maintained on young tobacco plants. The plants raised in sterile soil under insect proof conditions were as a rule inoculated when they had developed the first two to four true leaves and for any one experiment plants of the same age were employed. The test plants were always kept under observation for at least three weeks.

The reactions on differential hosts in all the four types indicated the presence of Virus A. *Phulwa* type 2 in addition indicated the presence of a weak strain of Virus X and the presence of a weak strain of this virus was also suspected in potato plants of variety *Darjeeling Red Round* exhibiting crinkle. Presence of Y Virus was indicated during one set of transmission experiments in *Phulwa* type one. These observations suggested the presence of the following Viruses.

Phulwa group 1 A+Y (*Solanum Virus* 3+*Solanum Virus* 2)
Phulwa group 2 X+A (*Solanum Virus* 1+*Solanum Virus* 3)
Phulwa group 3 A (*Solanum Virus* 3)
Darjeeling Red Round—Crinkle A+X (*Solanum Virus* 3+*Solanum Virus* 1)

The reactions on differential hosts and physical properties of Virus A which occurred commonly were studied in detail in order to confirm the identity of the virus. The culture of the virus recovered from *Phulwa* group 1 was used in these experiments.

Reactions on differential hosts

Nicotiana tabacum *L. variety* White Burley. Ten days after infection faint vein clearing is observed on younger leaves and within two weeks it is followed by green vein-banding on older leaves. On tobacco variety *Harrison's Special* similar but highly pronounced symptoms were observed (Plate XX, fig. 3).

Nicotiana glutinosa L. Infected plants show a peculiar tendency for the veins to thicken but with age the symptoms disappear (Plate XX, fig. 4).

Datura stramonium L. (*Jimson weed*). This plant could not be infected by mechanical inoculation but when shoot from the infected potato plant was grafted, the axillary shoots exhibited disease symptoms. In early stages slight pallor of the leaves was observed but this was followed by yellow speck-like mottle which usually commenced at the tip of the leaves. With the development of the leaves the symptoms became more pronounced and yellow areas interspersed with small green areas were observed. There was no necrosis (Plate XX, fig. 5). Efforts to transmit the disease from infected plants of *Datura stramonium* to healthy *Datura* plants by needle inoculation were unsuccessful.

Solanum nodiflorum Jacq., *Nicotiana rustica* L., *Petunia hybrida* Vilm and *Solanum nigrum* L. were not affected by the virus.

When infected shoot of *Phulwa* potato plant was grafted to virus free *President* potato plant it developed chlorosis and pale yellowish mottle but no deformity of the leaf was observed.

Properties of the virus

Exposure of the virus for ten minutes in a water bath at different temperatures shows that the activity of the virus is considerably reduced at 50°C. and that the thermal inactivation point lies between 50°C. and 55°C. The virus begins gradually to lose its activity at a dilution of 1 : 10 and becomes innocuous at a dilution of 1 : 200. The virus also begins to lose its activity after storage for 24 hours at room temperature and at 12°C. In the former case it entirely loses its activity after 48 hours of storage.

The reactions on differential hosts and the properties show that the virus described is *Solanum virus* 3 Murphy and M'Kay.

References

Murphy, P.A. and M'Kay, R. (1932). A comparison of some European and American Virus Diseases of the Potato, *Sci. Proc. R. Dublin Soc.* 20, N.S. 347-58

Smith, K.M. (1937). *Text Book of Plant Virus Diseases*. J. & A. Churchill Ltd., London

FURTHER OBSERVATIONS ON THE EFFECT OF FROST ON SOME ECONOMIC PLANTS OF DELHI

By Harbhajan Singh, M.Sc., Assoc.I.A.R.I., Imperial Agricultural Research Institute, New Delhi

(Received for publication on 29 October 1945)

In January, 1942, Delhi experienced a severe frost, resulting in damage to a wide variety of plants. The author then made some observations on the effect of frost and the information thus collected was recorded in a note published in a previous issue of this Journal [Singh, 1943]. References to previous records of frost damage were then made and are not repeated here.

During the winter of 1945, Delhi was again under the spell of a severe cold wave, experiencing several frosty nights; at times three to four such nights occurred in succession. The more severe frosts occurred during the first fortnight of January and on the night of January 12, a minimum temperature of 30°F. was recorded at the Imperial Agricultural Research Institute, New Delhi (the minimum temperature of 1942 was 28·3°F.). Though there were repeated attacks, the frost of 1945 was milder than that of 1942. This may have resulted in natural ' pre-hardening ' of the vegetation

to some extent. It is possible, the damage would have been much more pronounced if the weather preceding the frost had been warm like that of 1942.

The relevant temperature and humidity data are given in Table I.

TABLE I

Minimum and maximum temperatures and humidity recorded at the Imperial Agricultural Research Institute, New Delhi, from the 1st to 15th January, 1945

Date	Temperature (°F.)		Humidity	Date	Temperature (°F.)		Humidity
	Maximum	Minimum			Maximum	Minimum	
1	53·4	39·0	96	8	59·0	38·5	96
2	61·4	35·5	91	9	59·5	47·0	93
3	60·3	38·0	98	10	58·6	48·0	92
4	56·0	45·2	83	11	52·6	34·8	100
5	52·8	47·0	98	12	53·8	30·0	90
6	55·4	36·6	99	13	55·2	31·8	90
7	55·8	36·0	100	14	60·8	34·2	95
				15	63·5	37·0	95

It may be pointed out that all the plants mentioned in the present note are not local. At the Section of Economic Botany of the Imperial Agricultural Research Institute, New Delhi, a living collection of important wild and cultivated plants both indigenous and exotic is being maintained. It is mainly this material which forms the subject matter of this note.

Table II gives the names of plants observed for resistance or susceptibility to a temperature of 30°F. with brief notes on the nature of the damage.

TABLE II

List of plants with remarks on their resistance to frost

English or Indian name	Botanical name	Stage of the plant	Effect of frost
	Solanum ferox L.	Fruiting	Highly resistant.
	Solanum indicum L.	Just before flowering	Fairly susceptible. In a week's time new axillary shoots appeared.
Bari kateli	*Solanum incanum* L.	Fruiting	Fairly susceptible. Leaves were damaged.
Kateli	*Solanum xanthocarpum* Schrad & Wendl..	Fruiting	Fairly susceptible. Leaves were damaged.
	Solanum torvum Swartz	Fruiting and flowering.	Leaves of the upper branches were affected. Green fruits got shrunken.
Black Nightshade, *makoh*	*Solanum nigrum* L.	Fruiting	Fairly susceptible. Leaves and growing buds were damaged.
Currant tomato	*Lycopersicon pimpinellifolium* Mill.	Flowering and fruiting.	Leaves highly susceptible. Ripe and unripe fruits were very little affected.
	Lycopersicon hirsutum H. B. & K.	Flowering	Leaves and tender stems highly susceptible.
	Lycopersicon peruvianum Mill.	Flowering and fruiting.	Leaves and tender stems most affected. Fruits slightly affected.
Gooseberry, *rasbhari*	*Physalis peruviana* L.	Fruiting	Slight effect on leaves. The enlarged calyx of the fruit developed brown patches.

TABLE II—*contd.*

List of plants with remarks on their resistance to frost—contd.

English or Indian name	Botanical name	Stage of the plant	Effect of frost
Vegetable rennet	*Withania Coagulans* Dun.	Leafy	Highly resistant
Thorn apple, *safaid datura*	*Datura fastuosa* L.	Fruiting	Leaves badly damaged. Brown patches appeared on the green fruits.
Thorn apple, *kala datura*	*Datura fastuosa* L. var. *tatula*	Fruiting	Leaves badly damaged. Fruits had already ripened.
	Crotalaria retusa L.	Flowering and fruiting.	Leaves, flowers and buds were damaged.
	Crotalaria sericea willd.	Do.	Highly resistant
	Crotalaria striata Dc.	Do.	Highly susceptible
	Crotalaria anagyroides H. B. & K.	Just before flowering	Highly resistant
	Desmodium gyroides Dc.	Leafy	Leaves of top-most branches affected.
" Avaram bark "	*Cassia auriculata* L.	Leafy	Highly susceptible. New shoots appeared later.
Isafgol	*Plantago ovata* Forsk.	Leafy	Highly resistant
" Fleawort "	*Plantago psyllium* L.	Leafy	Do.
	Plantago lanceolata L.	Do.	Do.
	Plantago amplexicaulis cav.	Do.	Do.
Buckwheat	*Fagopyrum esculentum* Moench	Flowering	Highly susceptible. The top portions of branches with leaves and young flower buds were damaged. The plants resprouted.
Celery	*Apium graveolens* L.	Leafy	Highly resistant
Aramina	*Urena lobata* L.	Flowering and fruiting.	Leaves were completely frosted. Fruits had already matured.
Jangli bhendi	*Hibiscus ficulneus* L.	Flowering	Highly susceptible
Tukham malangan	*Lallemantia royleana* Benth.	Leafy	Highly resistant
Venezuela grass or Molasses grass.	*Melinus minutiflora* Beauv.	Leafy	All the aerial parts were severely damaged. The plants were cut back to the ground level and fresh growth appeared after about a fortnight.
Rye	*Secale cereale* L.	Vegetative	Highly resistant
	Aegilops ventricosa Tausch.	Do.	Do.
	Aegilops triuncialis L.	Do.	Do.
	Aegilops squarrosa L.	Do.	Do.
	Agropyron cristatum Boiss.	Do.	Do.
	Bromus japonicus Thunb.	Do.	Do.
Rescue grass	*Bromus unioloides* H.B.K.	Do.	Do.
	Phalaris minor Retz.	Do.	Do.
Wild barley	*Hordeum murinum* L.	Do.	Do.
Two-rowed wild barley	*Hordeum distichon* L.	Do.	Do.
Rye-grass	*Lolium temulentum* L.	Do.	Do.
Perennial rye-grass	*Lolium perenne* L.	Do.	Do.

SUMMARY

Data regarding minimum maximum temperatures and humidity from the 1st to 15th January, 1945, as recorded at the Imperial Agricultural Research Institute, New Delhi, are given.

The effects of frost on a number of plants, both indigenous and exotic, maintained at the Section of Economic Botany of the Institute, are recorded.

ACKNOWLEDGEMENT

The author is grateful to Dr B. P. Pal, Imperial Economic Botanist, for providing the necessary facilities in the compilation of these notes and also for suggesting several improvements.

REFERENCE

Singh, Harbhajan (1943). Effect of frost on some economic plants of Delhi. *Indian J. agric. Sci.* 13, 279-82.

REVIEWS

The constituents of wheat and wheat products

By C. H. BAILEY (Published by *Reinhold Publishing Corporation, New York, 1944*) *pp. 332 Price $6·50*)

THOUGH it is great privilege to be asked to review such a book, the undersigned feels rather shy in passing any judgement on this great book written by the great man Dr C. H. Bailey who is considered to be an outstanding cereal chemist of the world and a leader in this field of science. It was from him that the reviewer acquired the knowledge of cereal chemistry and technology while he was his student in the University of Minnesota, U. S. A., sometime ago.

After going through the book one may be inclined to feel that it contains details of numerous items which may be only of a historical interest. Whilst this may be true, the important point to be taken into consideration is the masterly grasp of the subject and the painstaking thoroughness with which Dr Bailey has brought together, in a systematic and readily available form, the enormous literature which has accumulated mostly during the past half century, beginning with Becarris famous "glutan working experiments", published as early as 1745. The reviewer is sure all the cereal chemists and technologists will gratefully acknowledge the real service that Dr Bailey has done to them by placing before them such a comprehensive and unique compilation which is designed to serve as a guide and source of reference to the complex and massive literature on wheat chemistry.

Every cereal chemist and technologist will wish to own a copy of such an excellent book, which happens to be the first and the only one of its kind that has so far been written.

The book contains 16 chapters of which seven deal with the nitrogenous compounds and three with carobohydrates. The remaining six are devoted, respectively, to the liquids, minarals halogens (together with sulphur and selenium), acidity, pigments and vitamins.

Dr Bailey has given a hint in his introduction that he is planning to bring out a second volume which will deal with the dynamic biochemistry of wheat dealing with, among other things, enzymes, bread making, wheat processing, etc. There is no doubt that such a book will get enthusiastic reception and these two volumes, this and the one which Dr Bailey contemplates publishing, will form the *vade macum* of the cereal chemist.

There is a complete list of references at the end of each chapter, the total number of citations being 1024. The book contains an author index and an adequate subject index.—R.S.

PLANT QUARANTINE NOTIFICATION

Notice No. 5 of 1945

THE following quarantine regulations have been received in the Imperial Council of Agricultural Research. Any one interested is advised to apply for detailed information to the Secretary, Imperial Council of Agricultural Research, New Delhi.

1. B.E.P.Q.—396, Supplement No. 2, dated 6 July 1945 issued by the United States Department of Agriculture.
2. B.E.P.Q.—379 (Revised), Supplement No. 2, dated 30 June 1945 issued by the United States Department of Agriculture.
3. B.E.P.Q.—502, Supplement No. 1 Revised dated 30 June 1945 issued by the United States Department of Agriculture.
4. B.E.P.Q.—416, Revised, Supplement No. 1, dated 7 August 1945 issued by the United States Department of Agriculture.

MGIPC—M—III-1-10—31-3-47—600.

The Editorial Committee, in its work of examining papers received for publication, is assisted in an honorary capacity by a large number of scientists working in various parts of India.

Editorial communications including books and periodicals for review should be addressed to the Secretary, Imperial Council of Agricultural Research, Publication Section, New Delhi.

Communications regarding subscription and advertisements should be addressed to the Manager of Publications, Civil Lines, Delhi.

Instructions to Authors

Articles intended for The Indian Journal of Agricultural Science should be accompanied by short popular abstracts of about 300 words each.

In the case of botanical and zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

References to literature, arranged alphabetically according to authors' names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets; when the author's name occurs in the text, the year of publication only need be given in brackets. If reference is made to several articles published by one author in a single year, these should be numbered in sequence and the number quoted after year both in the text and in the collected references.

If a paper has not been seen in original it is safe to state ' Original not seen '.

Sources of information should be specifically acknowledged.

As the format of the journals has been standardized, the size adopted being crown quarto (about $7\frac{1}{8}$ in. $\times$ $9\frac{5}{8}$ in. cut), no text-figure, when printed, should exceed $4\frac{1}{2}$ in. $\times$ 5 in. Figures for plates should be so planned as to fill a crown quarto plate, the maximum space available for figures being $5\frac{3}{4}$ in. $\times$ 8 in. exclusive of that for letter press printing.

Copies of detailed instructions can be had from the Secretary, Imperial Council of Agricultural Research, New Delhi.